Dynasonde and VIPIR Ionosonde

Field Site Requirements
Basic and Research Capabilities

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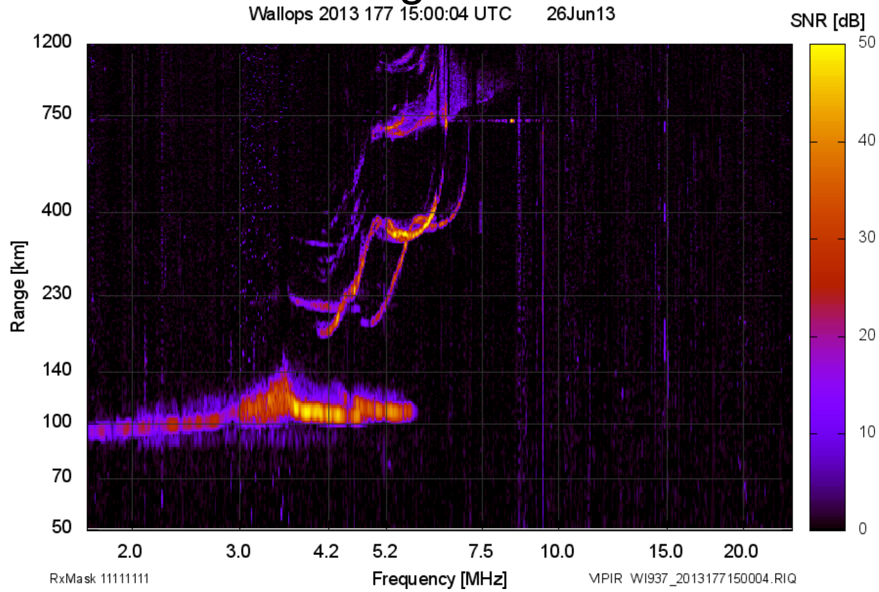
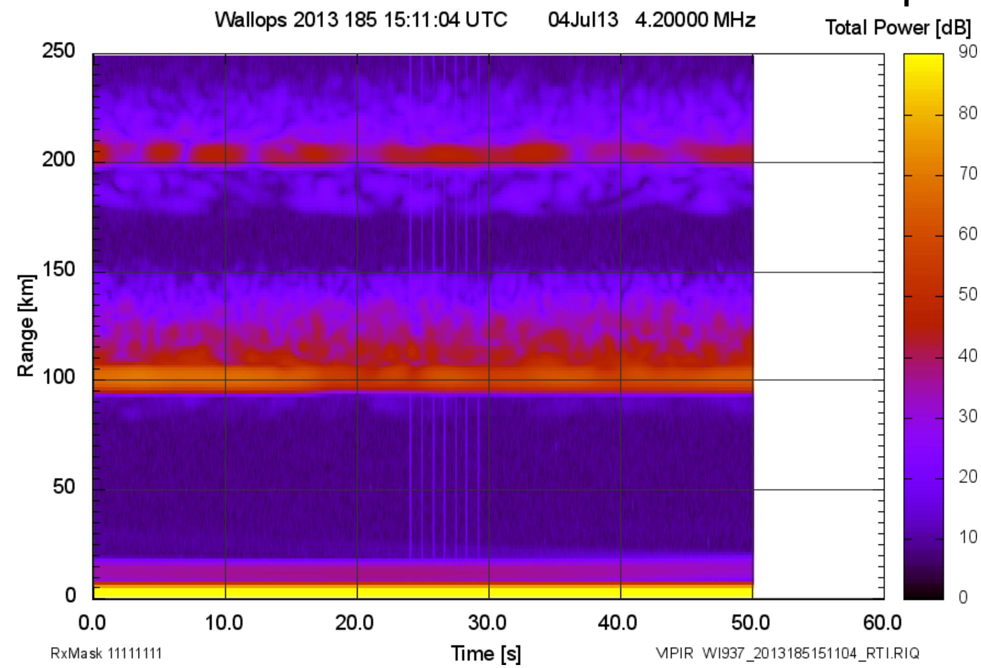
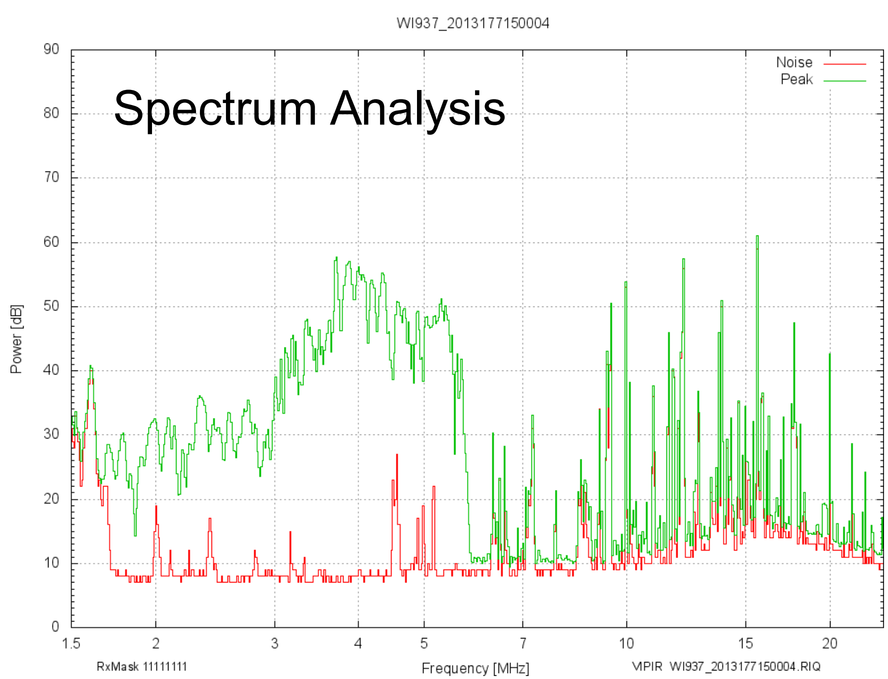
VIPIR is the Hardware

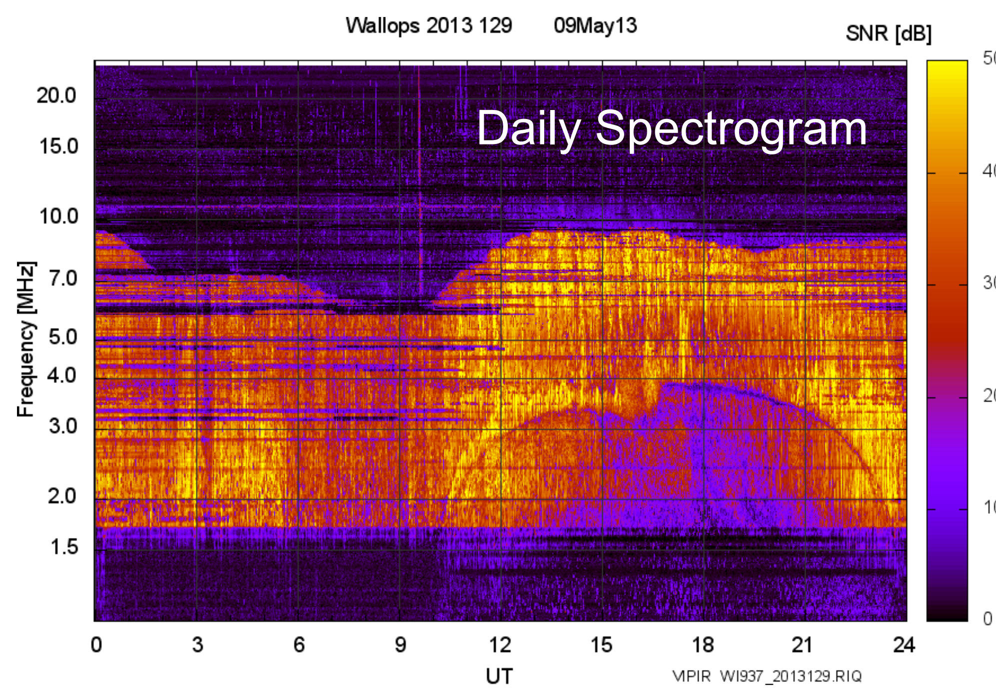
SNR Ionograms



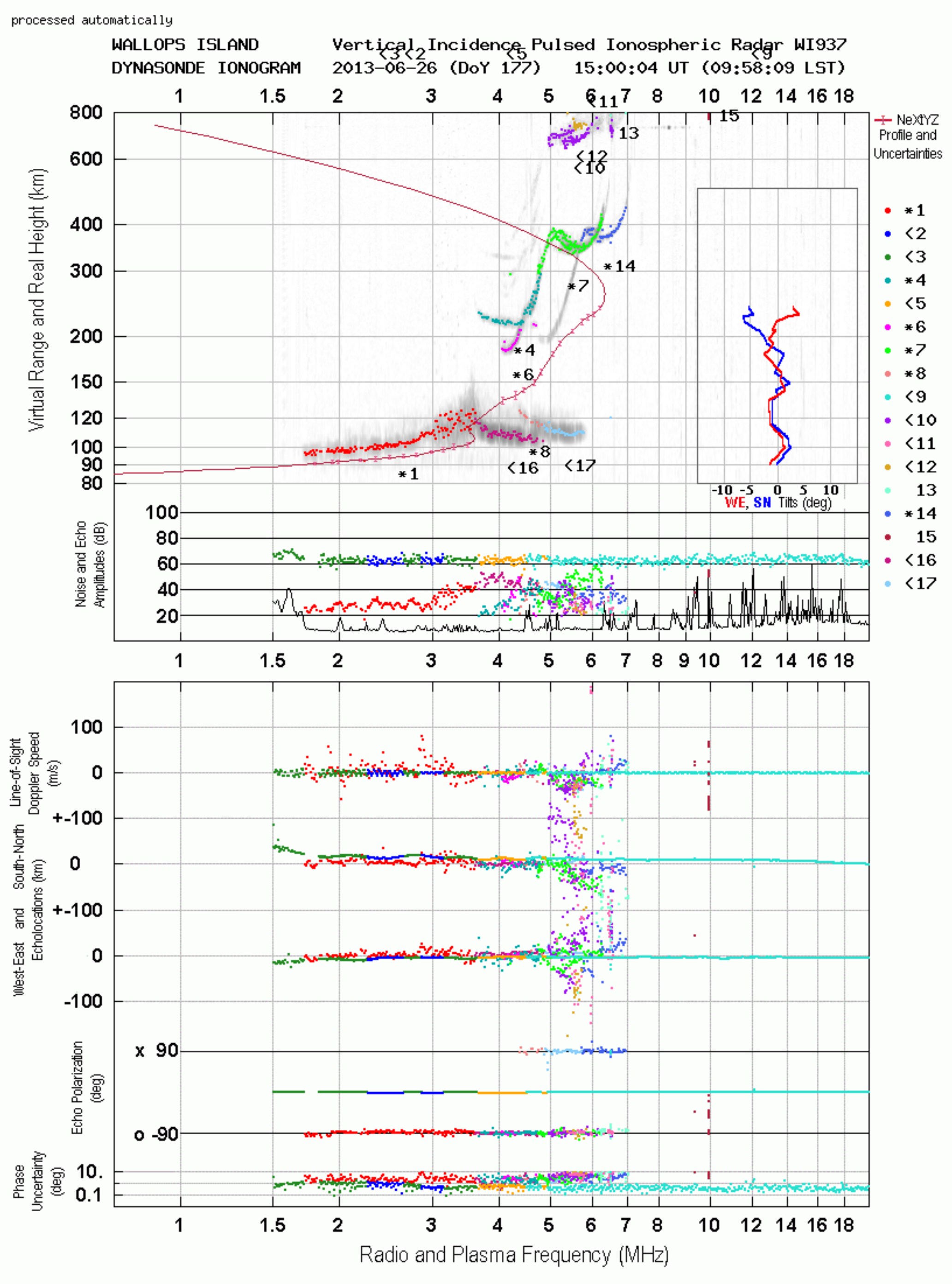
Fixed Frequency







Dynasonde is the Software



- Echo Detection
- Trace Classification
- Ionogram Scaling
- 3D echo-location
- Electron Density Profile
- Tilt Profile

Vertical Incidence Pulsed Ionospheric Radar

Very high interference immunity: IP3 > 45 dBm

High Dynamic Range: 115(I) +30(V) dB

Direct RF sampling 14 bits at 80 MHz

Fully digital conversion, receiver and exciter

Waveform Agility: 2 µs to 2 ms pulse/chip width

USB-2 Data and Command/Control Interfaces

8 coherent receive channels; Frequency: 0.3 – 26 MHz

4 kW class AB pulse amplifier: 3rd harmonic < -30 dBc

Precise GPS timing possible for bi-static operation

Radar software Open Source C code; runs under Linux

Upgrades for the VIPIR Mark II

- FPGA based digital receiver
- 16 bit, 120 MHz ADC
- USB3 data transfer
- Improved analog front end
- Improved receive antenna pre-amplifiers
- Contemporary computers and data storage
- Options:
  - High power low pass transmit harmonic filter
  - Rubidium oscillator for oblique phase measurements

VIPIR Mark II

Jang Bogo Antarctic Research Station
Korean Polar Research Institute

Wallops Island VIPIR hardware

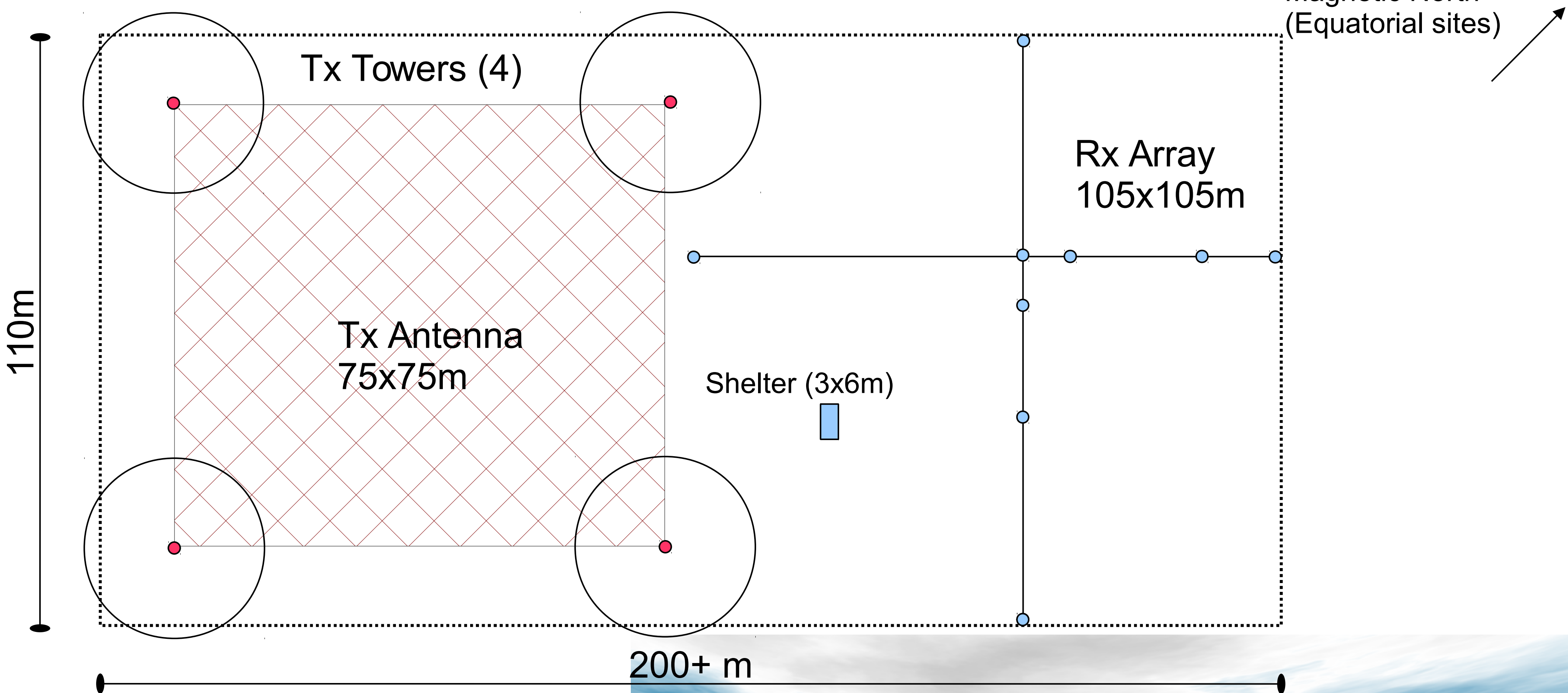
Standard 19" rack, 46" tall

Installation “classes”

- Research
    - Major research facility for plasma physics, propagation research and ionosphere discovery. Performance is primary, cost and footprint are secondary concerns.
- Average
    - Ionosphere monitoring and geophysical research. A compromise between of cost and capability.
- Small
    - Ionospheric monitoring. Cost and footprint are primary concerns and limitations.
- Transportable
    - Ionospheric measurements from various locations. Mobility is the primary concern.

There is approximately a factor of 10 in performance between these classes

World Class VIPIR Field Site



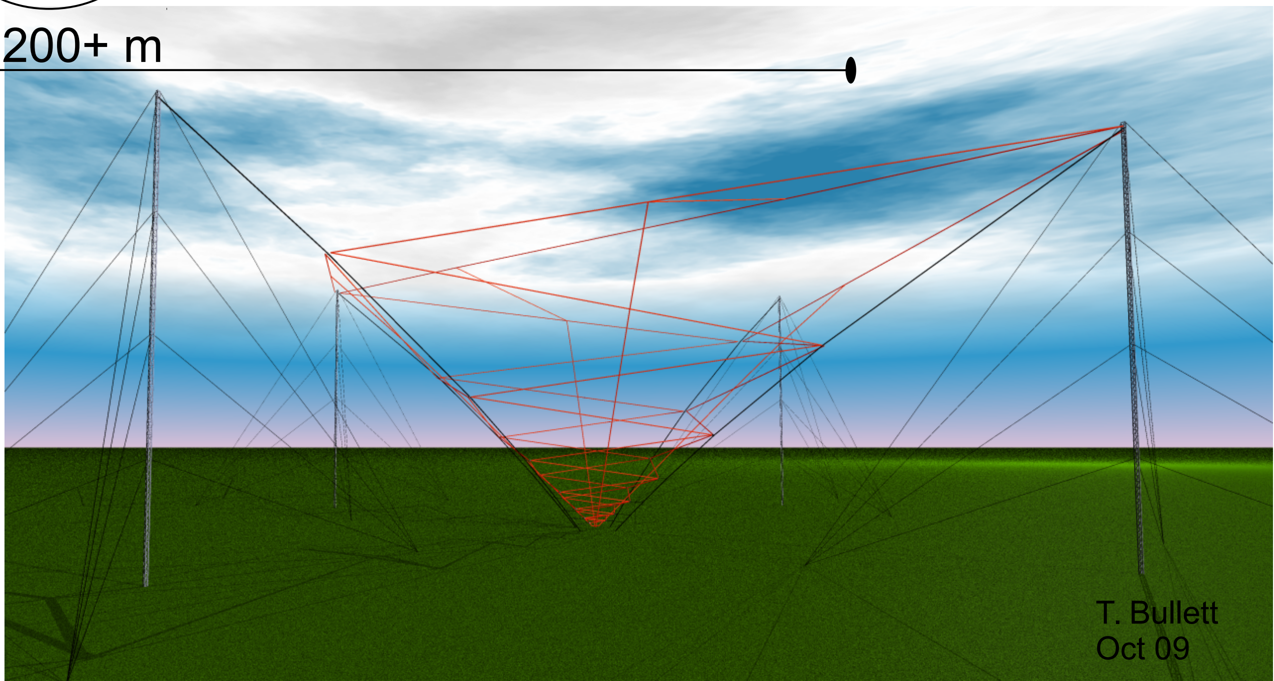
8 channel HF radar

8 or 10 element Rx array

Log-periodic Tx antenna

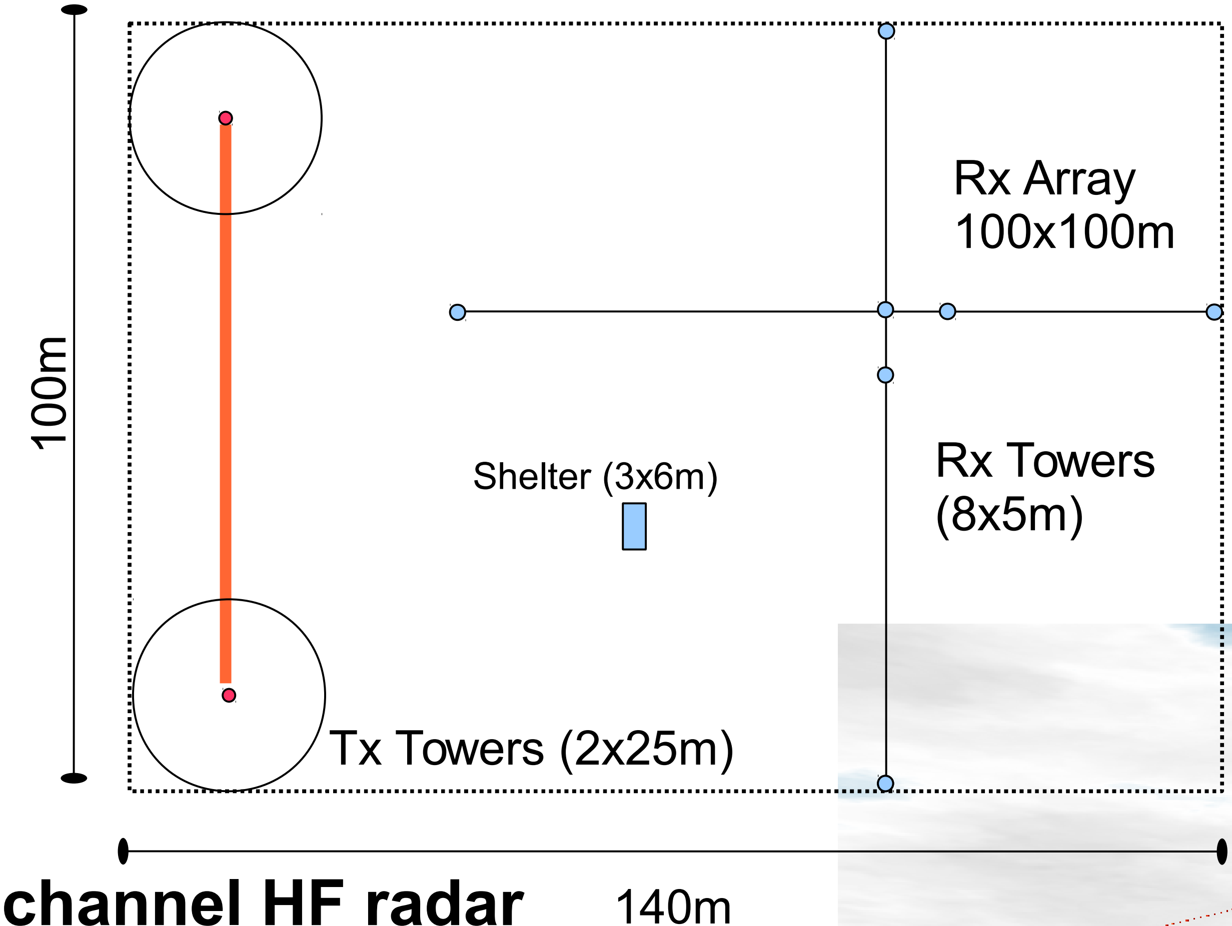
35m steel towers (4)

5 to 10 acre footprint



Intermediate VIPIR Field Site

Magnetic North
(Equatorial sites)



8 channel HF radar

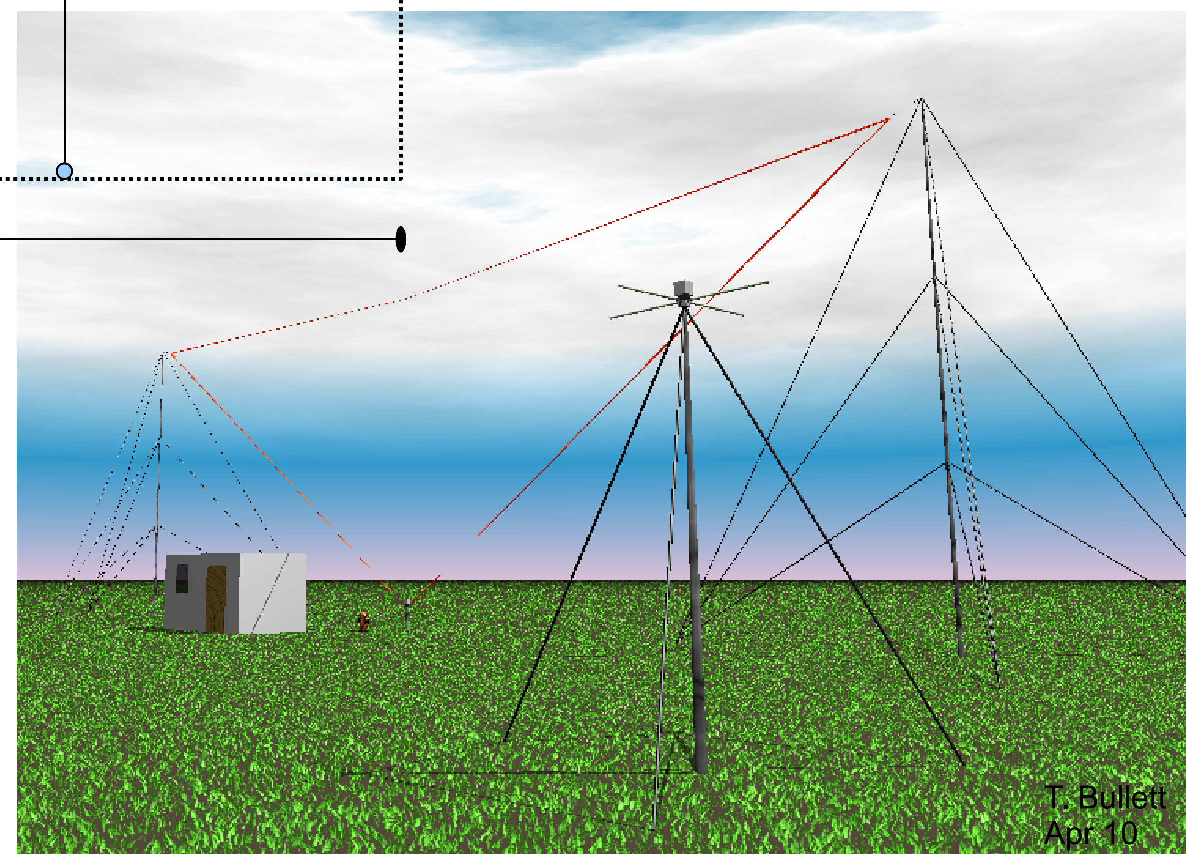
8 element Rx array

Inverted Delta Tx antenna

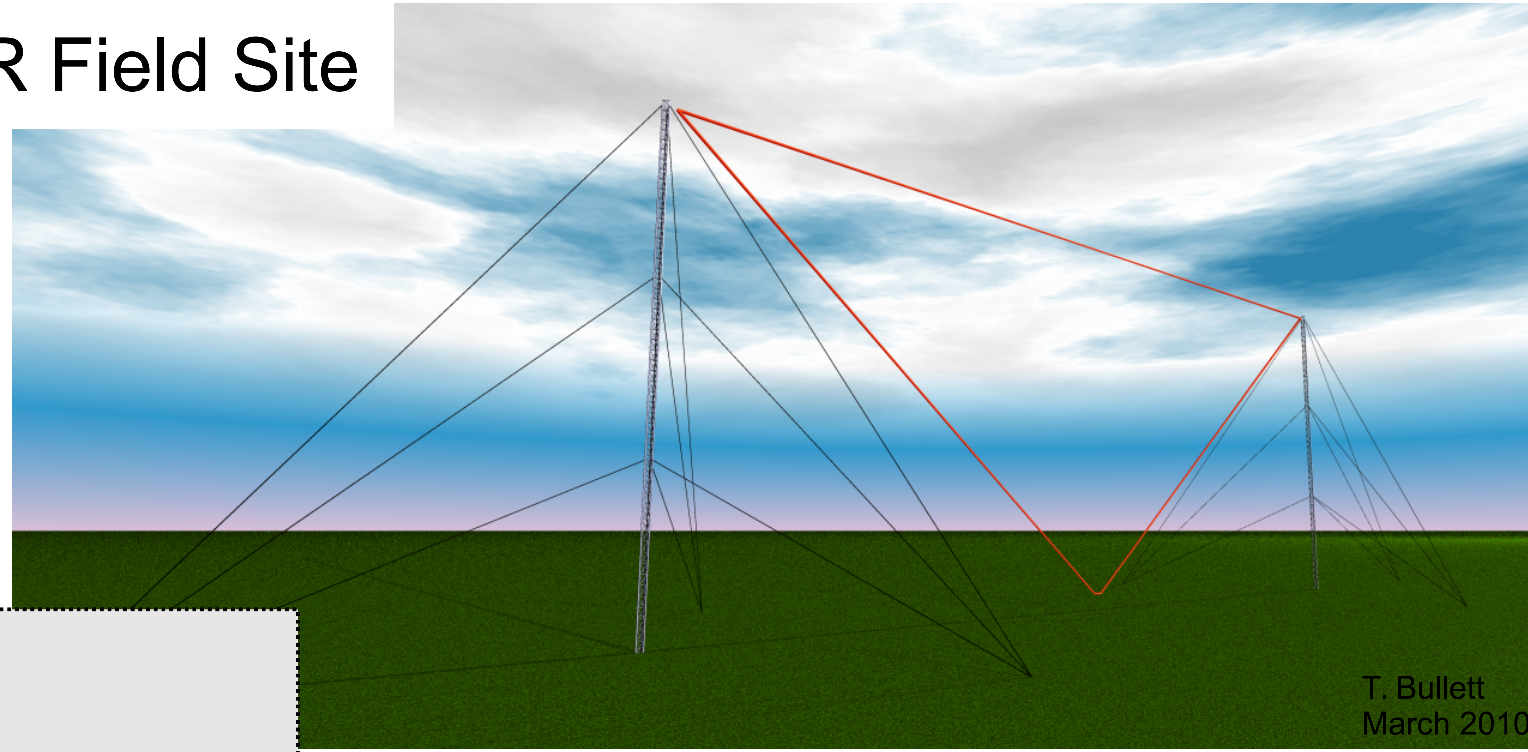
25m Tx Towers (2)

5m Rx towers (8)

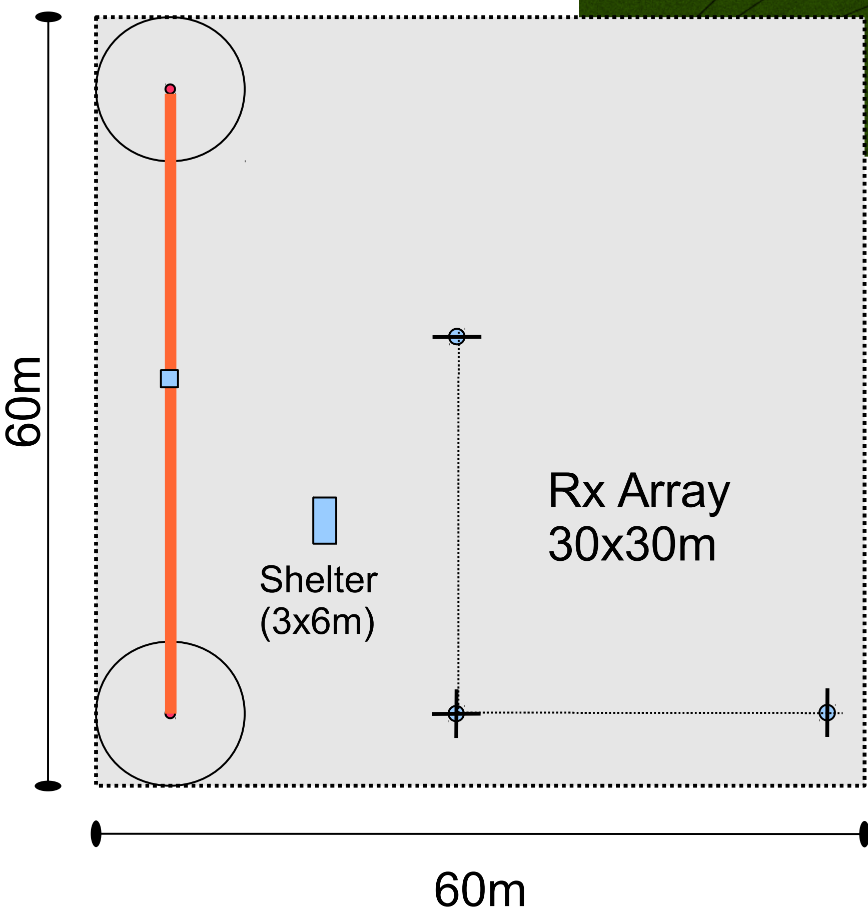
3.5 acre footprint



Reduced VIPIR Field Site



Magnetic North
(Equatorial sites)



4 channel HF radar

4 element Rx array

Inverted Delta Tx antenna

15m Tx poles (2)

5m Rx poles (4)

< 1 acre footprint

Virtual walk-through:
http://www.ionosonde.com/images/Ionosonde_Tour.avi

Transportable VIPIR

Photographs of VIPIR prototype antennas designed for use on a 40 ft fishing boat.

Portability is key

Antennas engineered for temporary install & transport

4 or 8 channel HF radar

2-8 element Rx array

Mini-Delta Tx antenna or custom

Facilities

- Climate Controlled Shelter
  - 3mx3m minimum
  - Larger space enhances research
- 25,000 BTU Air Conditioner (Large window model)
- 220v x 15A or 110Vx30A power
- Internet connection
  - 128kbps minimum ; 1Mbps recommended
- Absence of:
  - High Voltage Power Lines
  - Industrial electrical noise
  - Other HF users (receive and transmit)
  - MF transmitters (AM Broadcast or NDB)

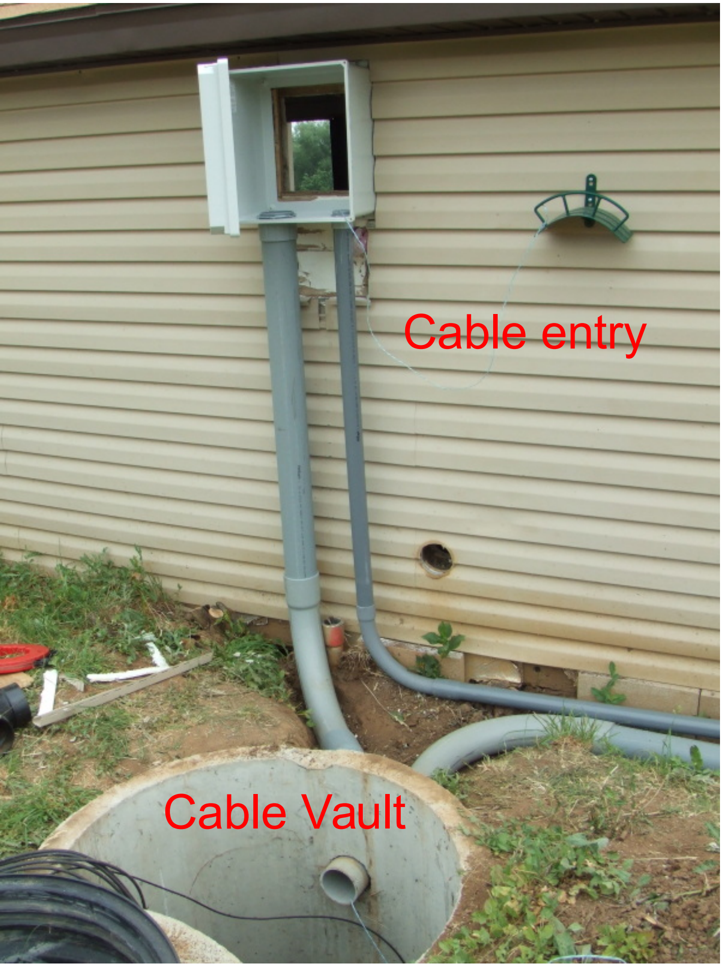
Local Construction

- Shelter
- Receive anchors
- Receive poles
- Transmit anchors
- Transmit towers
- RF Cable conduit
- Cable Vault
- Your existing Tx antenna!

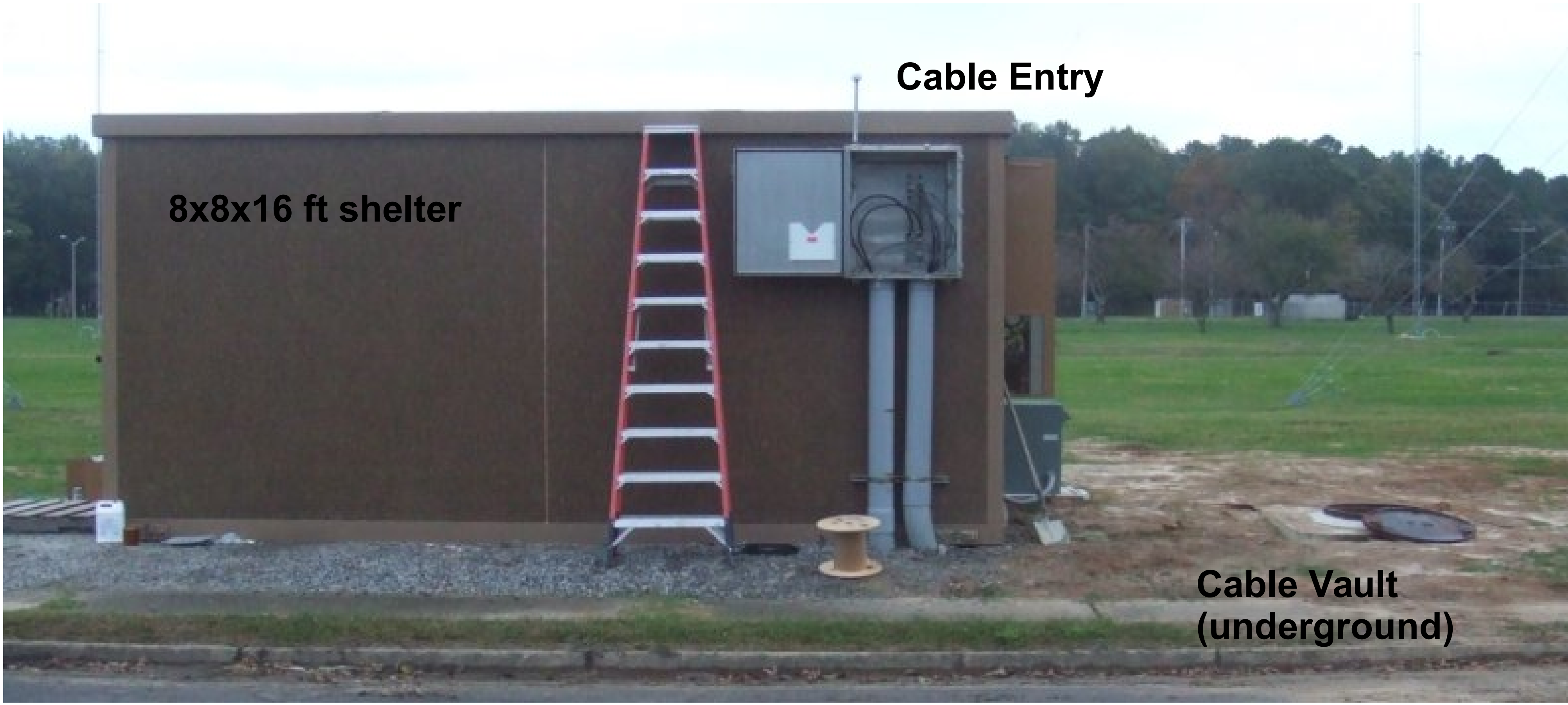
Local Parts (Optional)

- 19” equipment rack
- Rack Slides
- Power Conditioner
- UPS
- Keyboard
- Mouse
- Monitor
- KVM switch

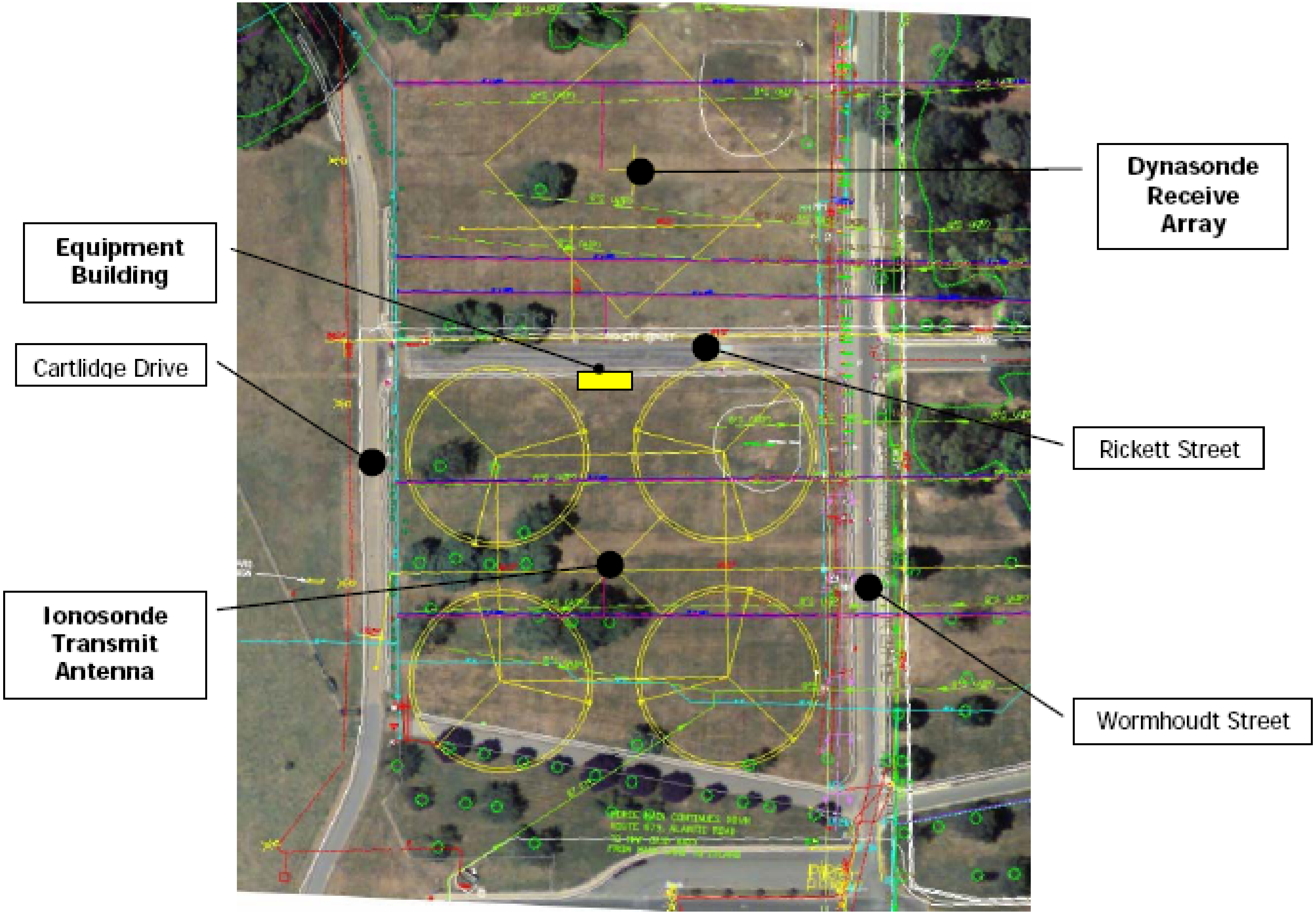
Boulder Site Photos



Wallops Shelter



Wallops VIPIR Field Site

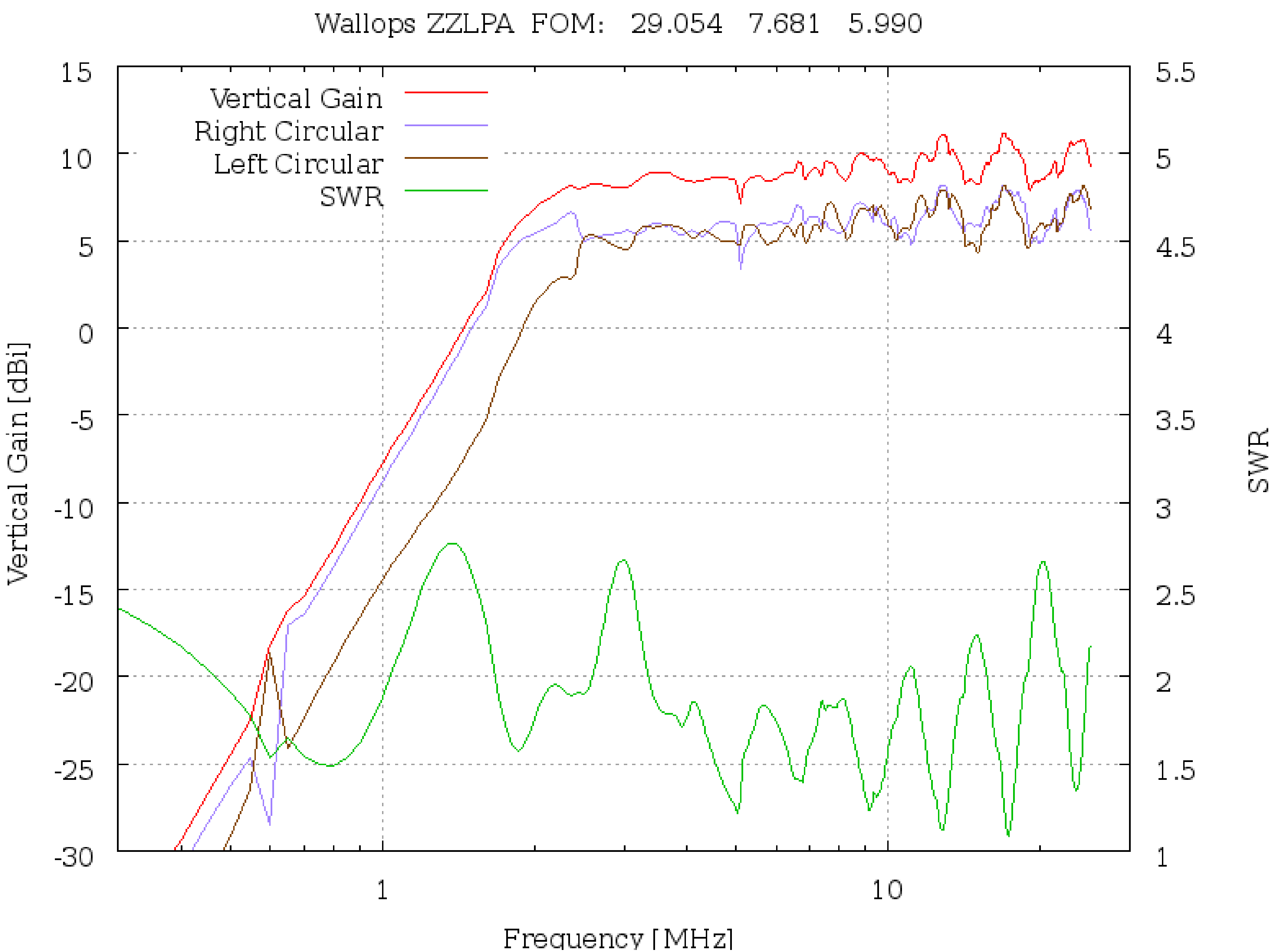


Long Term “World Class Observatory” being provided by NASA for continued research and routine observations

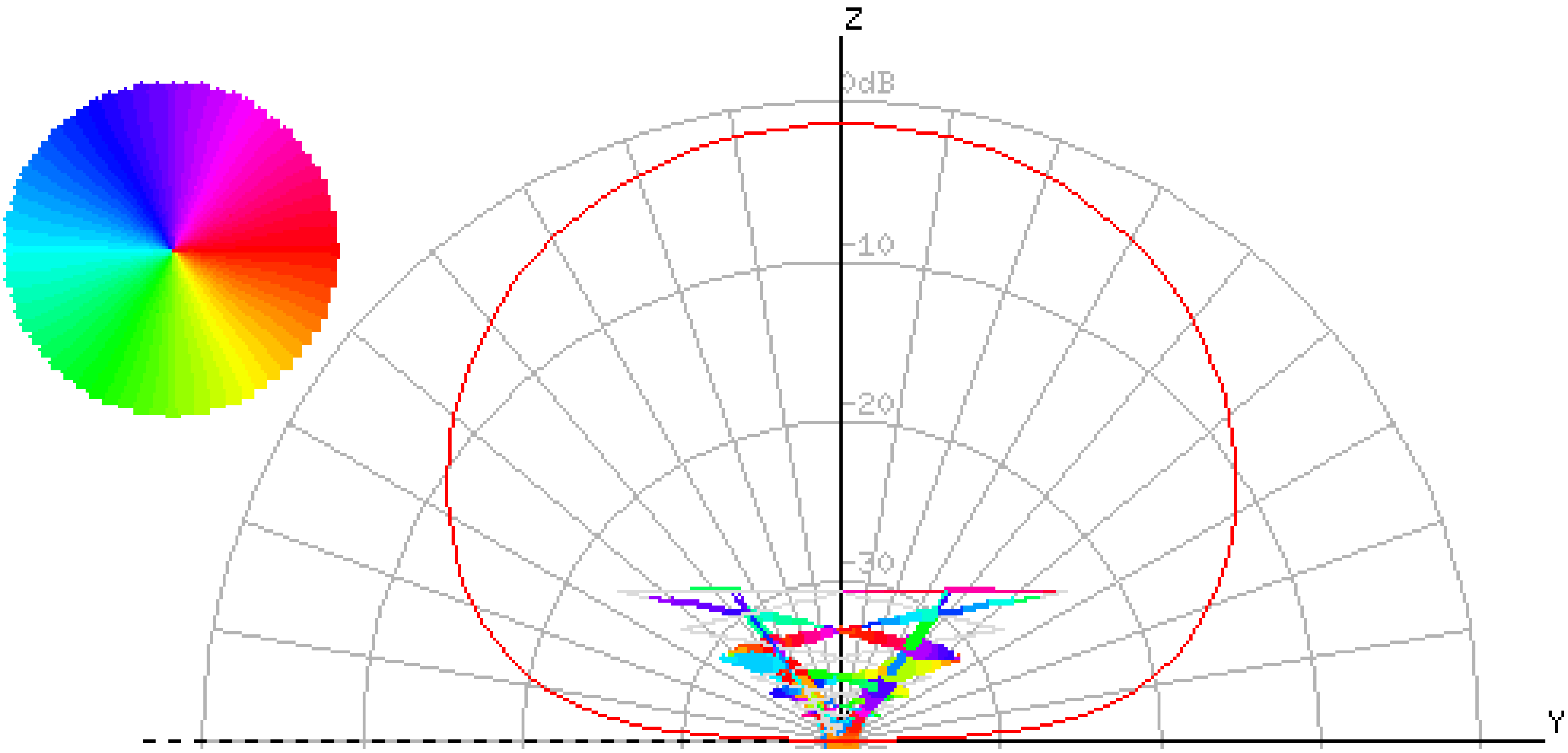
Wallops Island: September 2006

Wallops Island Tx antenna

Transmit Antenna Performance



Typical ZZLPA Pattern

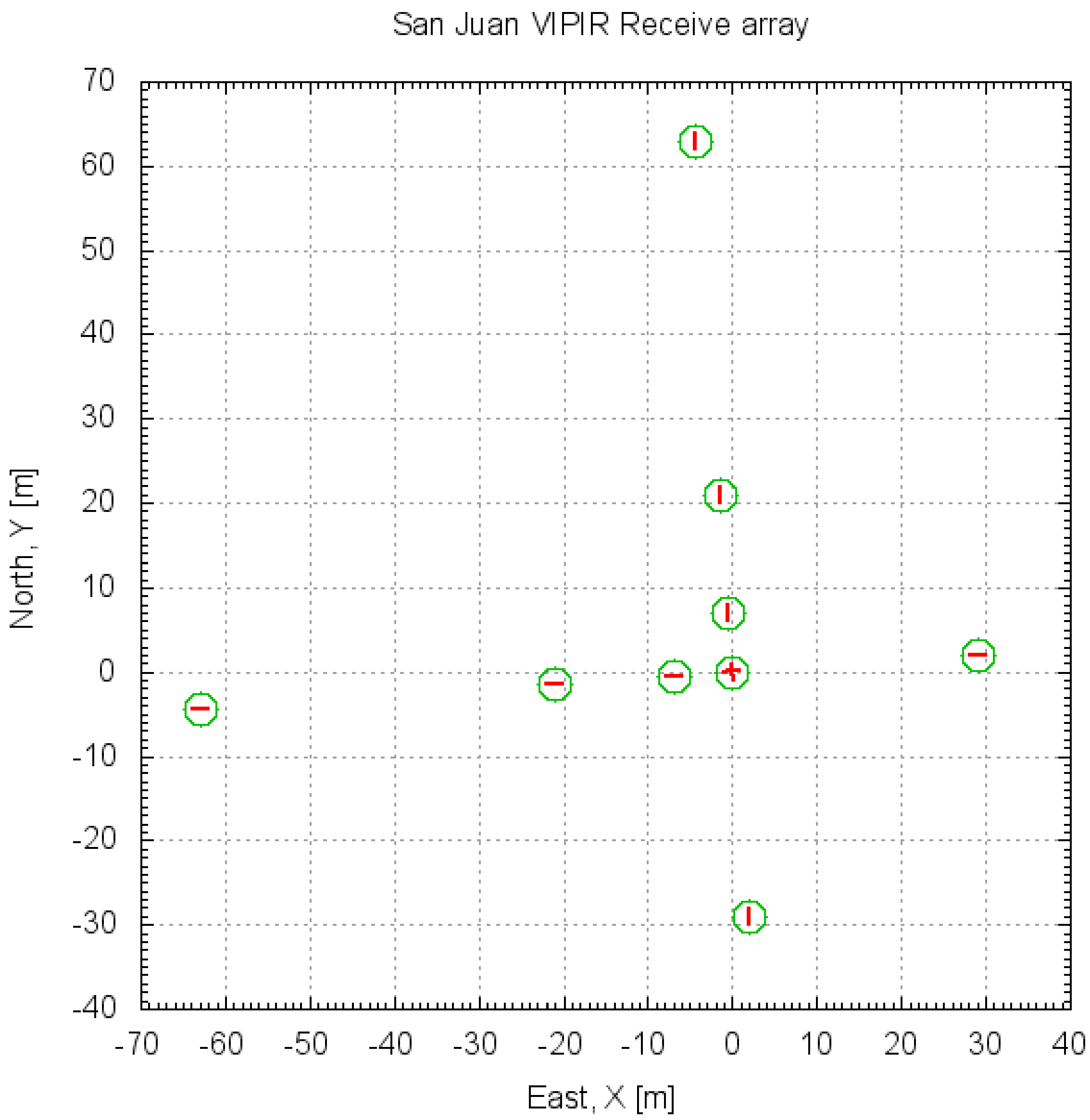


Inverted Delta Transmit Antenna

San Juan Observatory
"Small" : 15m tall x 45m long

Receive Antennas

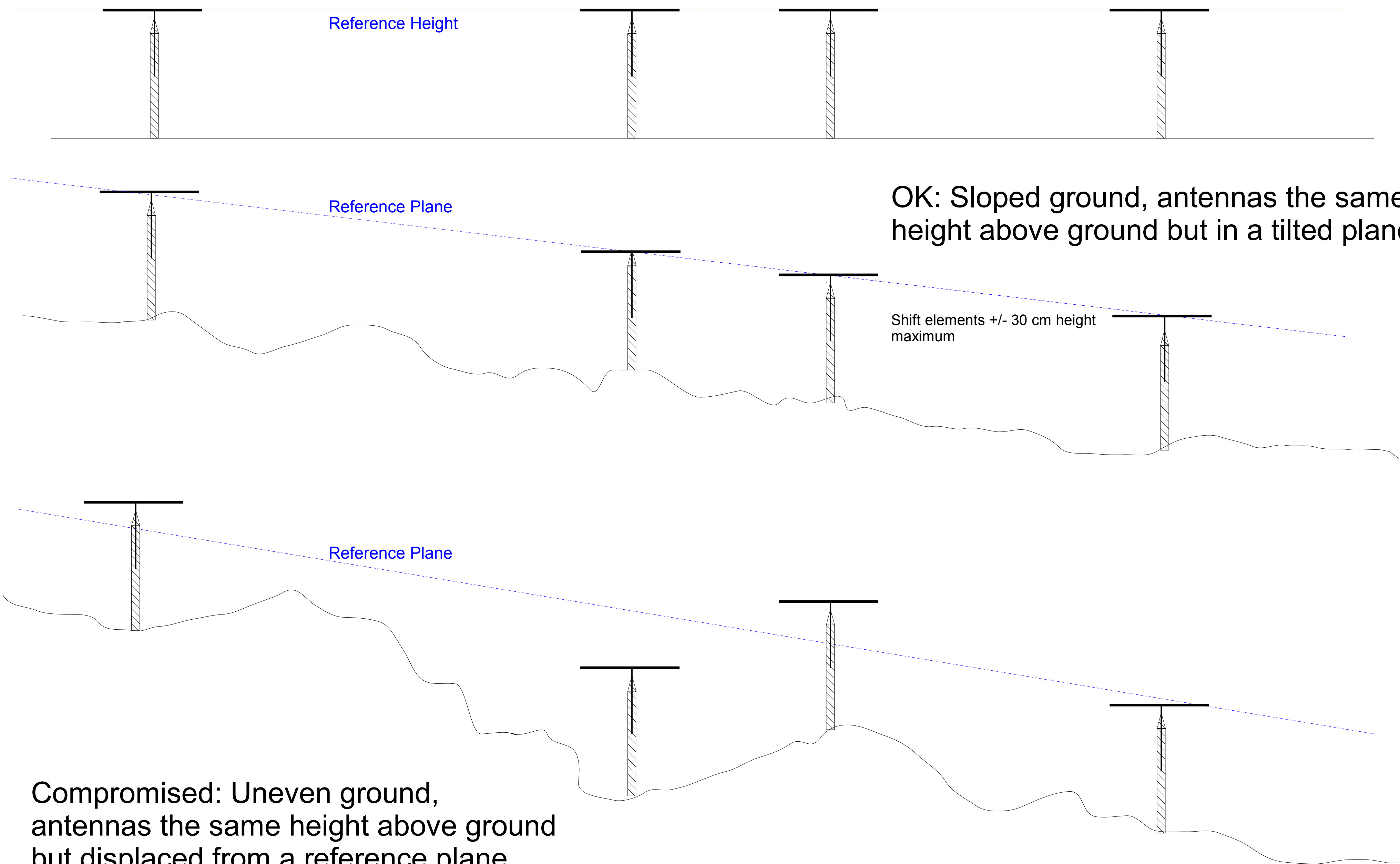
2m crossed dipoles



Antennas at locations -9 -3 -1 0 +4
Gives separations of 1 2 3 4 5 6 7 8 9 13
Units of 7m

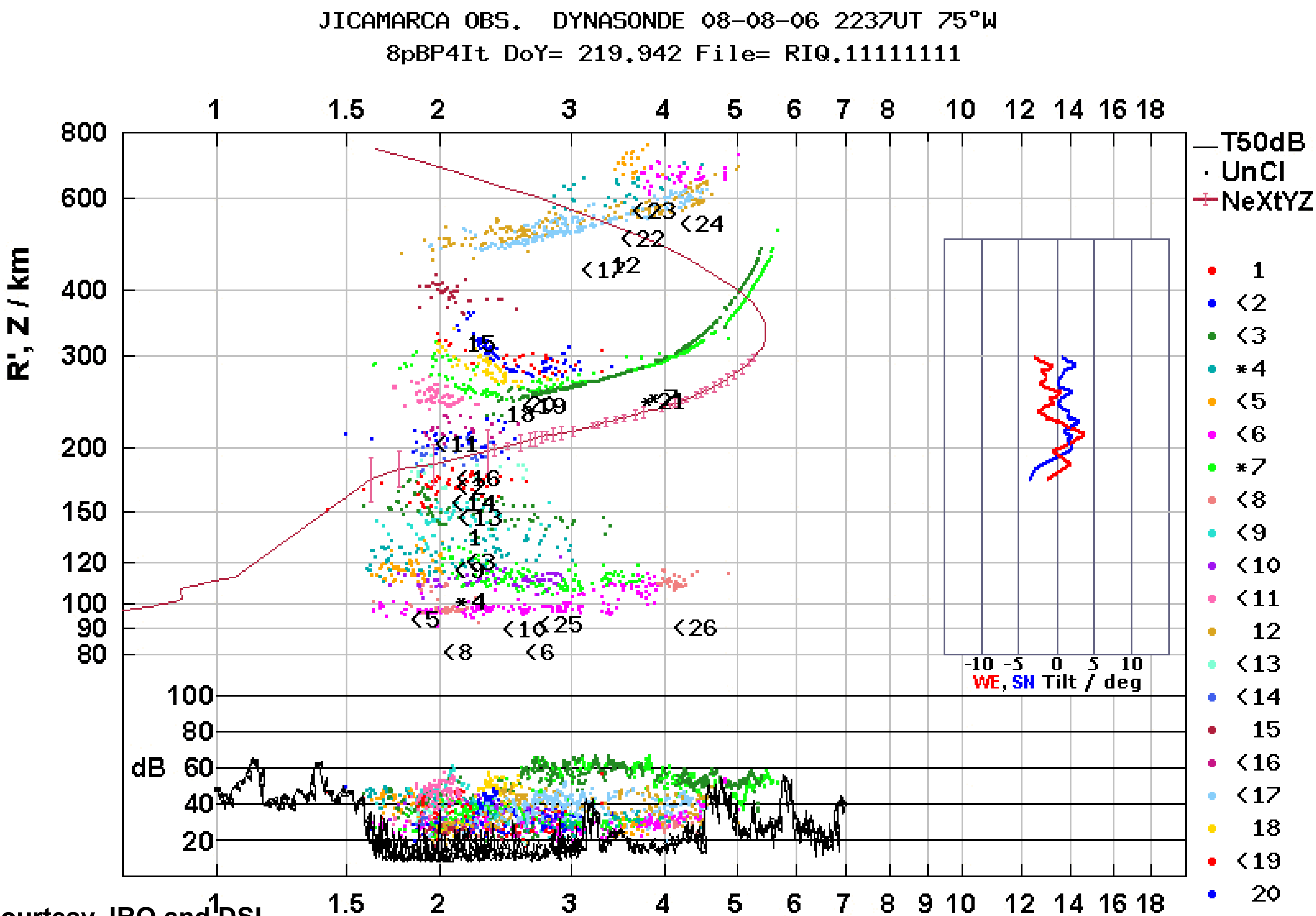
Uneven Ground

Ideal: Uniform, Horizontal ground, antennas the same height above ground



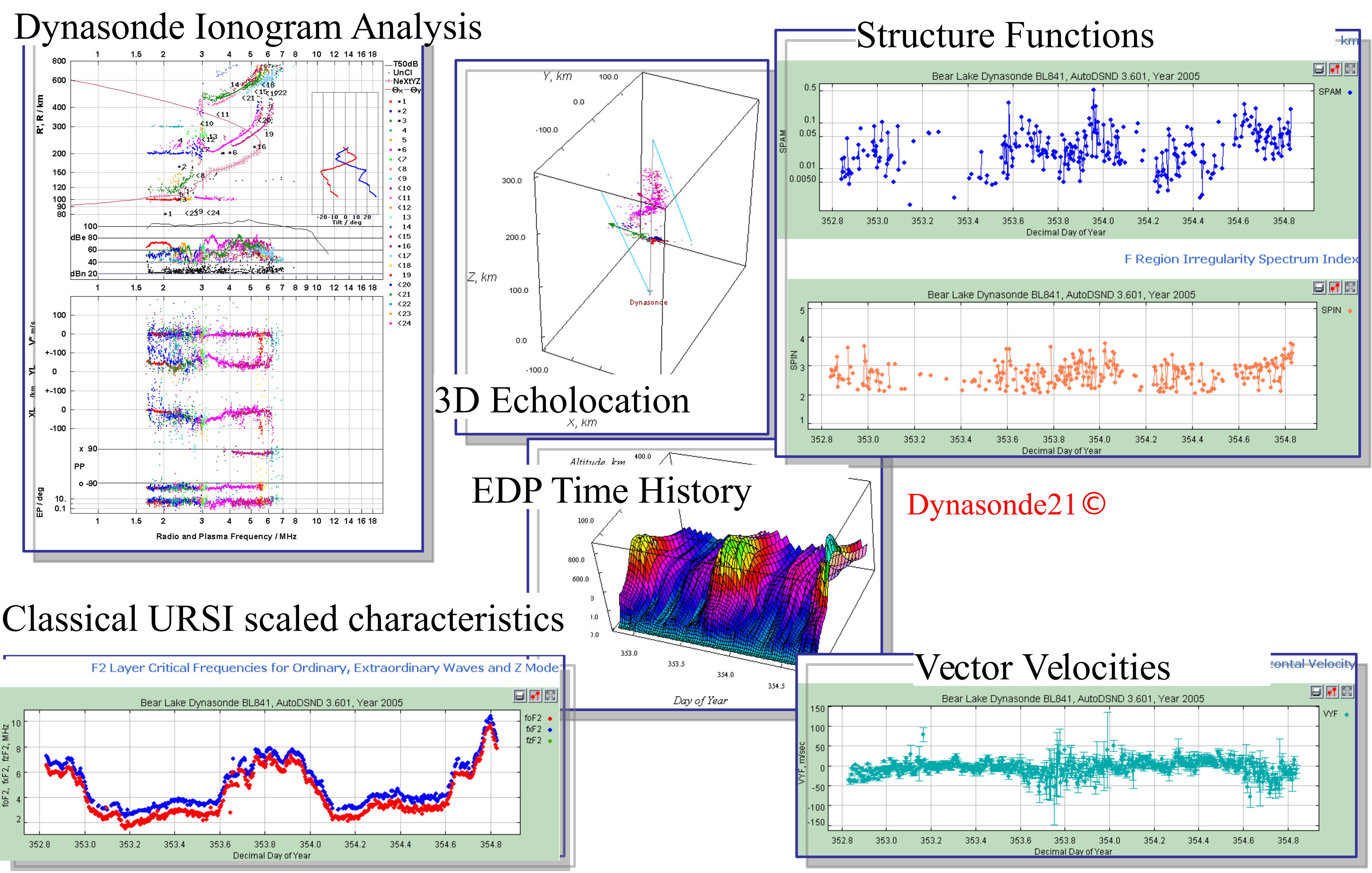
Ionogram Analysis: Dynasonde21

Jicamarca, Peru : VIPIR ionogram : Dynasonde21 Analysis



Courtesy JRO and DSL

Dynasonde21



Dynasonde is the name for methodology of ionospheric radio sounding based on the physical notion of radio echo and on a comprehensive use of phase information in it.

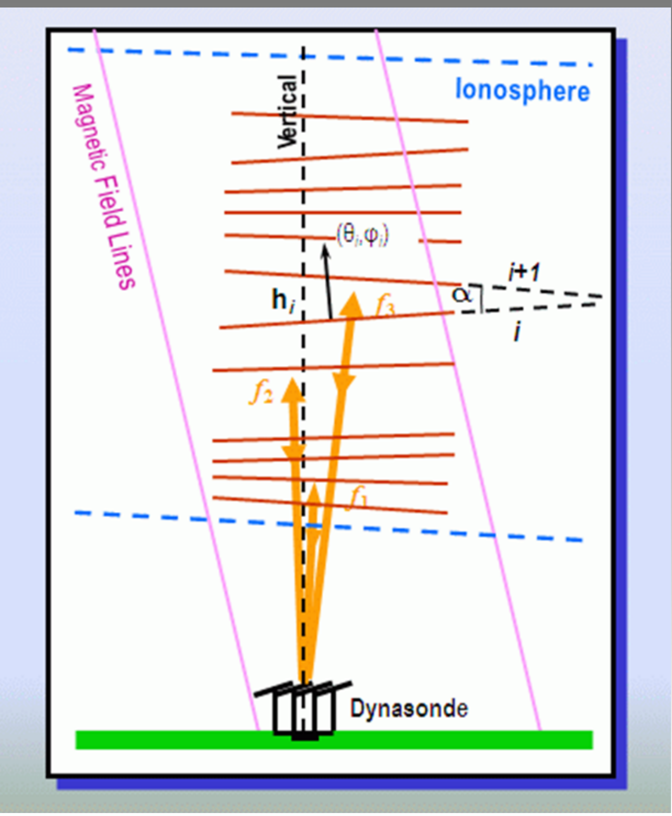
Echo is a physical object characterized by 7 physical parameters (two angles of arrival, group range, Doppler, polarization, phase range, amplitude) plus their uncertainties. Processing the list of the echoes instead of traditional amplitude-based image analysis is the distinctive property of a Dynasonde system. This technique turns radar into a measuring system, not merely imaging system.

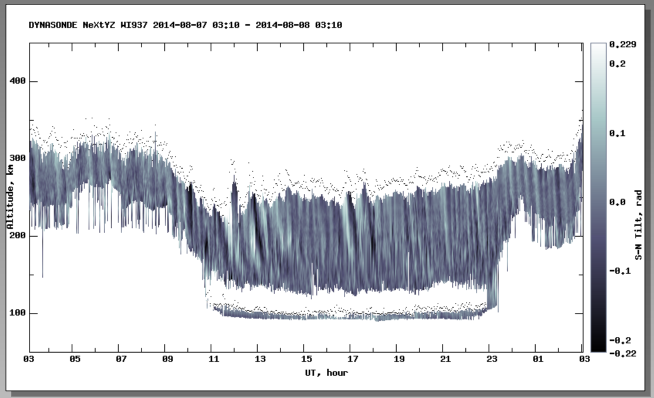
Feature important for Acoustic Gravity Wave studies:

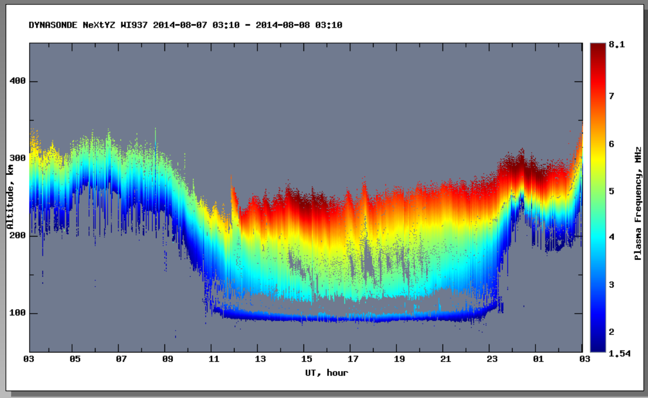
Precision measurements of the range and the angles of arrival for every echo.

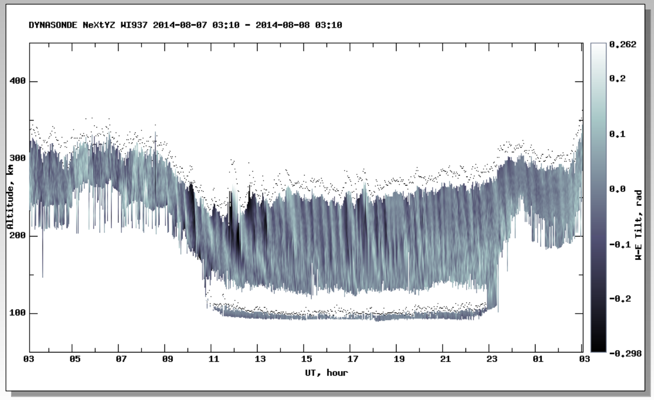
NeXtYZ ("Next Wise"), 3-D Plasma Density Inversion Procedure

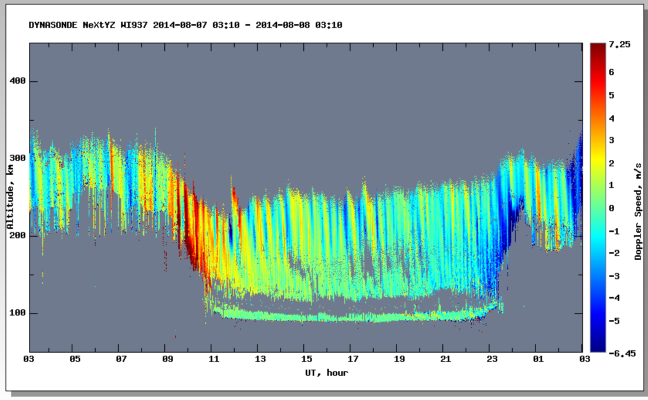
provides parameters of the Wedge Stratified Ionospheric Model. [Zabotin et al., Radio Sci., 2006]



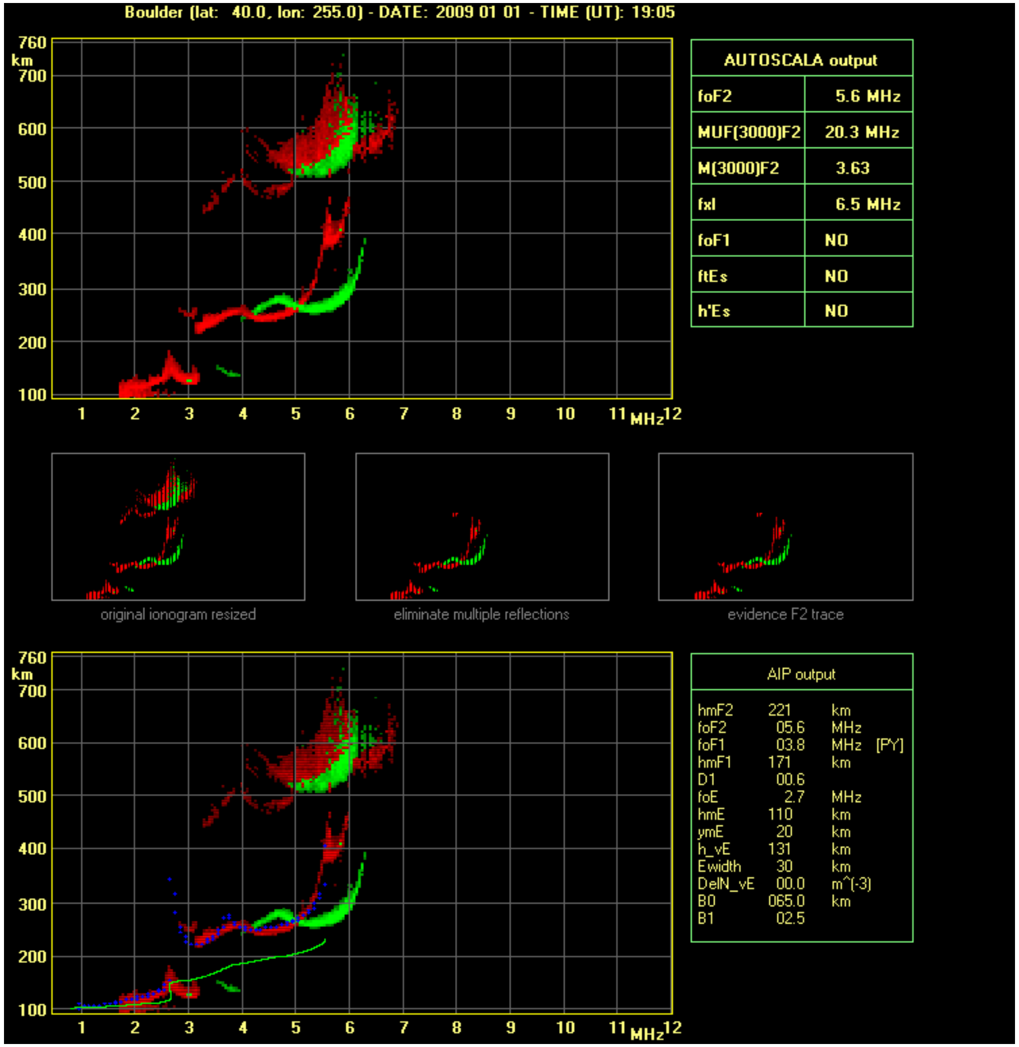


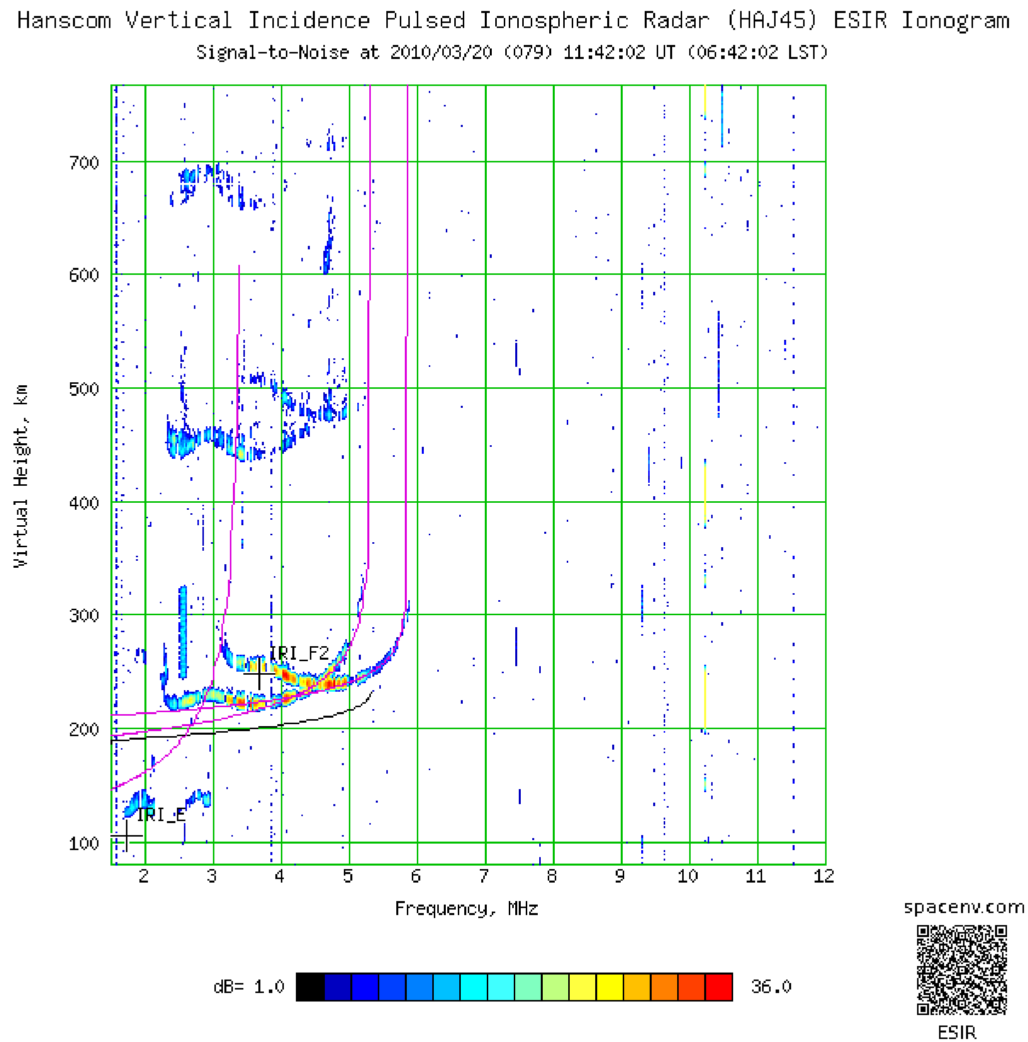






Automatic Scaling Options





Autoscala from INGV

ESIR from SEC

Contact these vendors for terms and conditions of use for this software

Frequency Allocation

- Ionosonde is an active transmitting system
  - RF License needed
- Ionosonde frequency use is non-standard
  - Regulatory agencies used to HF comms allocations
  - Exclusive use of narrow band channels
- Antenna radiation pattern is Vertical Incidence
  - Little RFI beyond a few km
- Some 200 ionosondes have operated since 1930
  - Precedents exist

A bad frequency allocation can cripple the instrument

Frequency Allocation Issues

Ionosondes do not fit into standard frequency allocations

- 20 kHz bandwidth vs 5 kHz allocations

Exclusive Use vs Temporary Access

- Occupies any 5 kHz channel 1 second every minute

Complete MF-HF Spectrum coverage required

- At least 1-16 MHz

A few specific narrowband channels can be excluded

- Standard time frequencies (2.5, 5.0, 10.0, 15.0, 25.0 MHz)

Exclusion of whole bands is disastrous

- Aeronautical, Marine, Land Mobile, Fixed Terrestrial

Site-Specific allocations that address specific RFI issues are required!

Transmitter Technical Data

Frequency Range: 0.5 to 26 MHz

4 kW peak power, 5% duty cycle max. 200W average.

Logarithmically spaced frequencies (typical 0.5% spacing)

4 to 16 pulses per frequency, 100 Hz rate

70 microsecond (15 kHz bandwidth) pulses

Raised cosine pulse: Low out-of-band emission

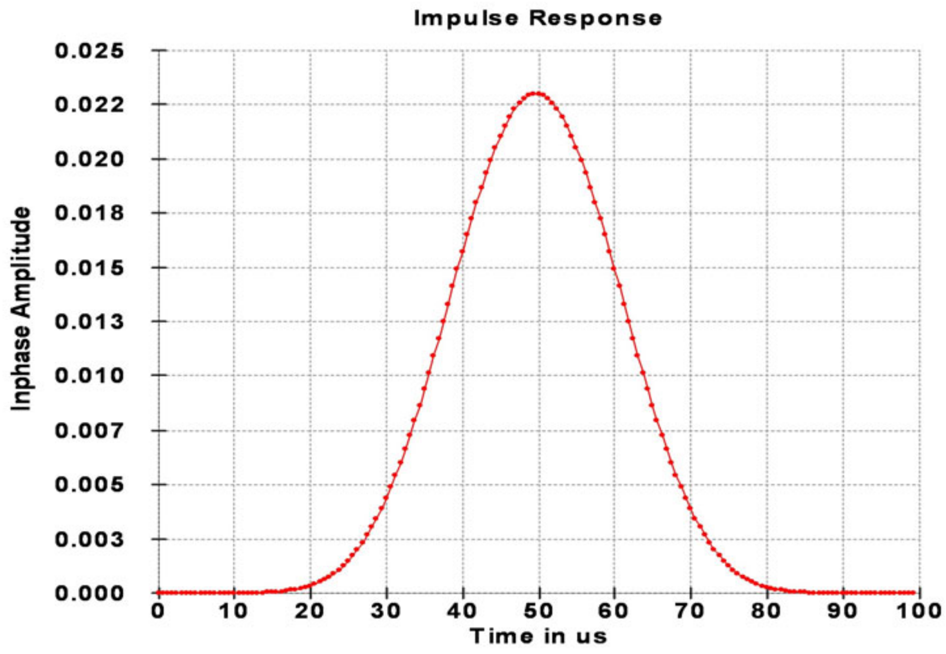
Very low harmonics

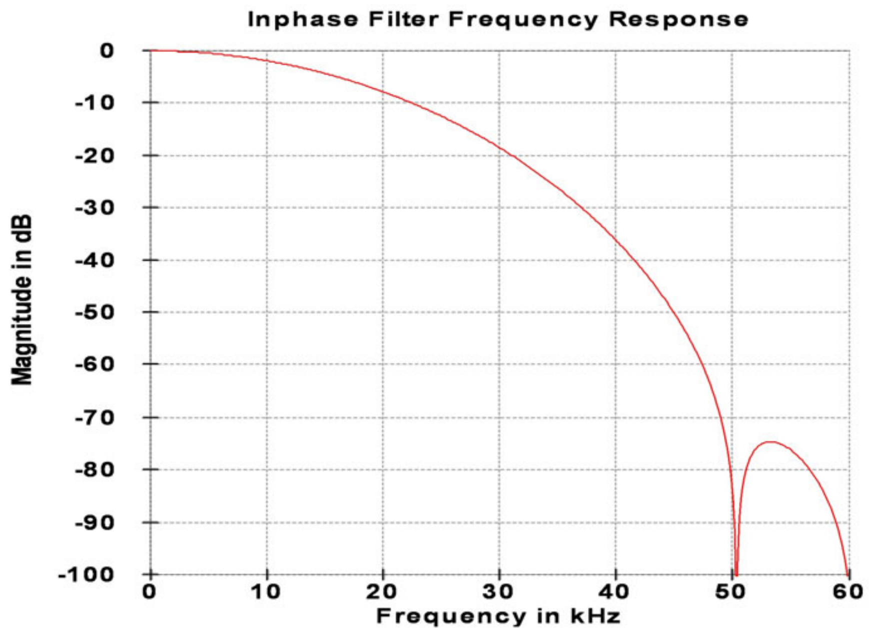
Typical 0.1 second channel use per frequency

1 to 5 minute repeat rate

Total channel use: 0.1%: Low probability of RFI

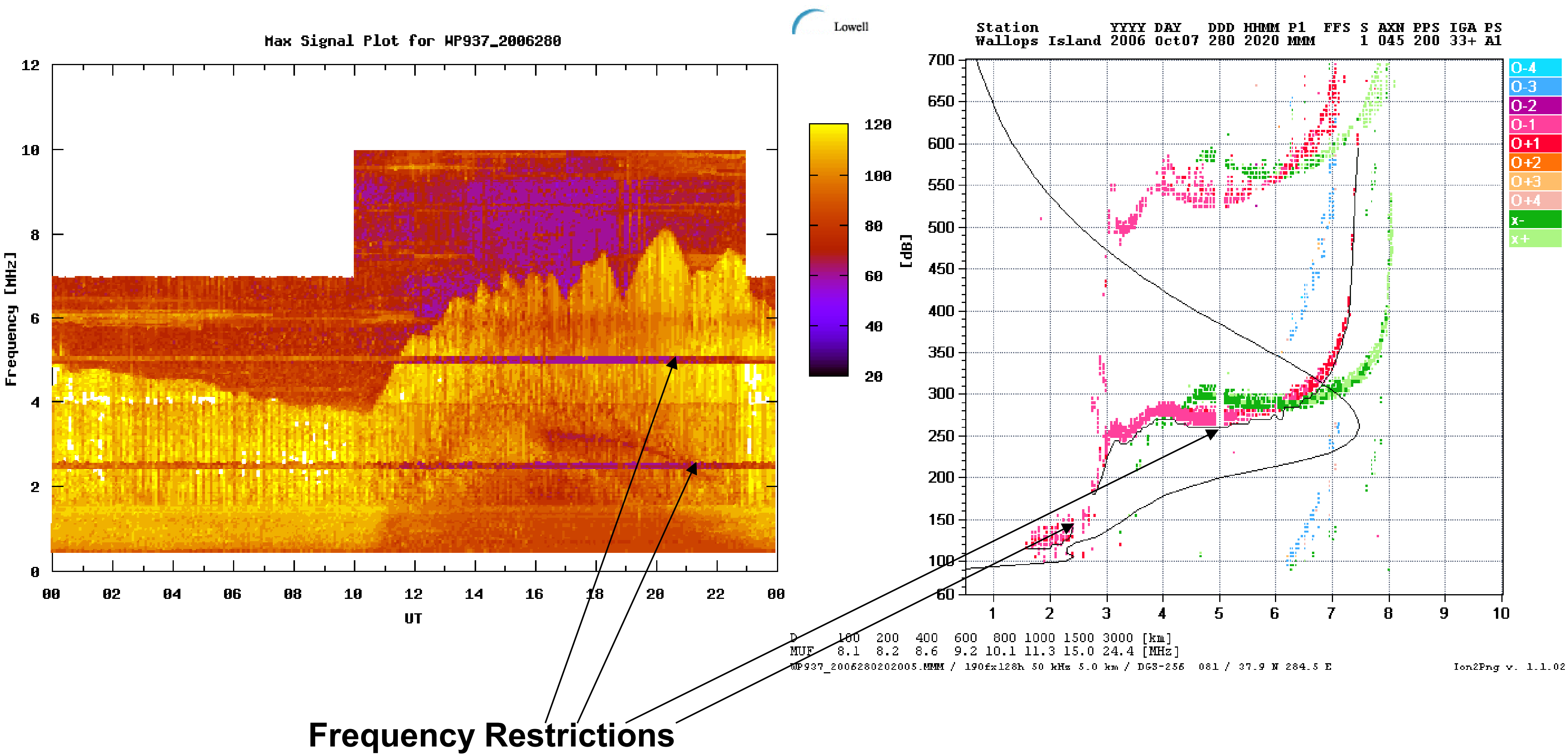
VIPIR Waveform





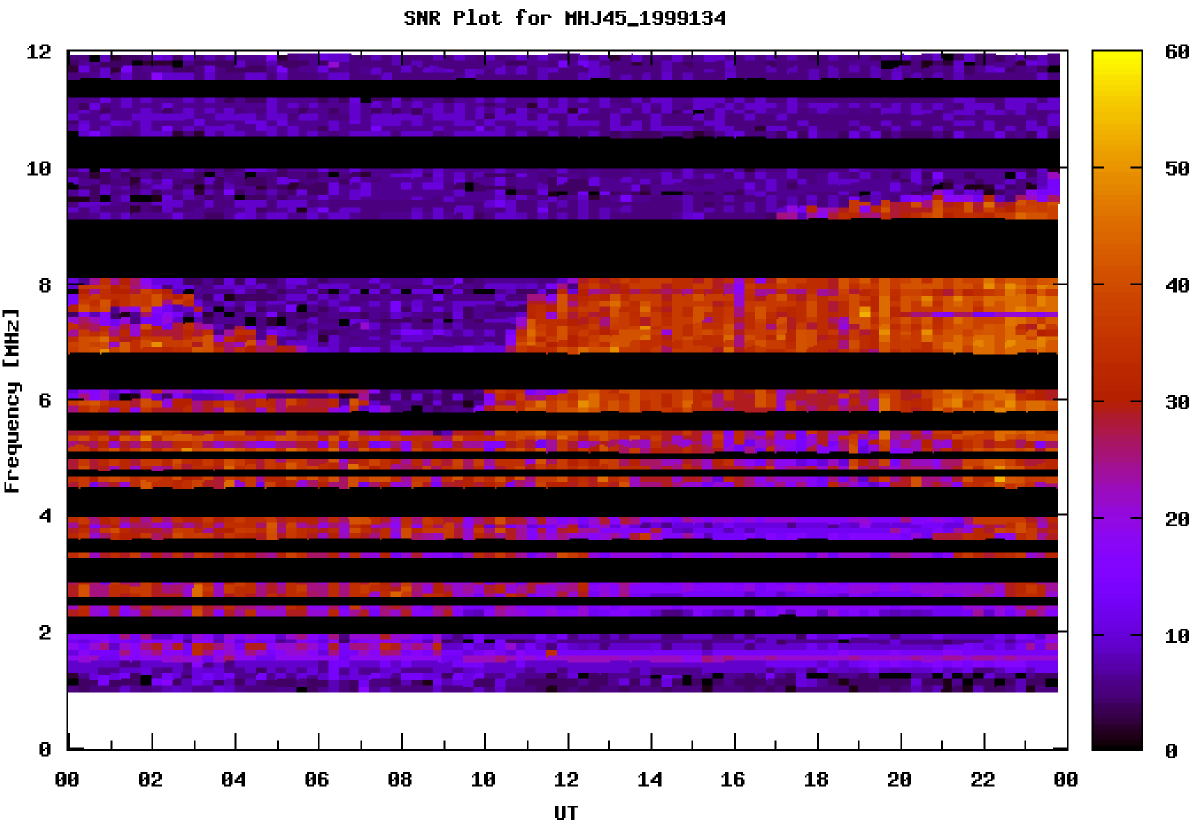
The receiver impulse response of a raised cosine to the 4th power provides good balance between range resolution and channel occupancy without substantial artifacts in either the time or frequency domain

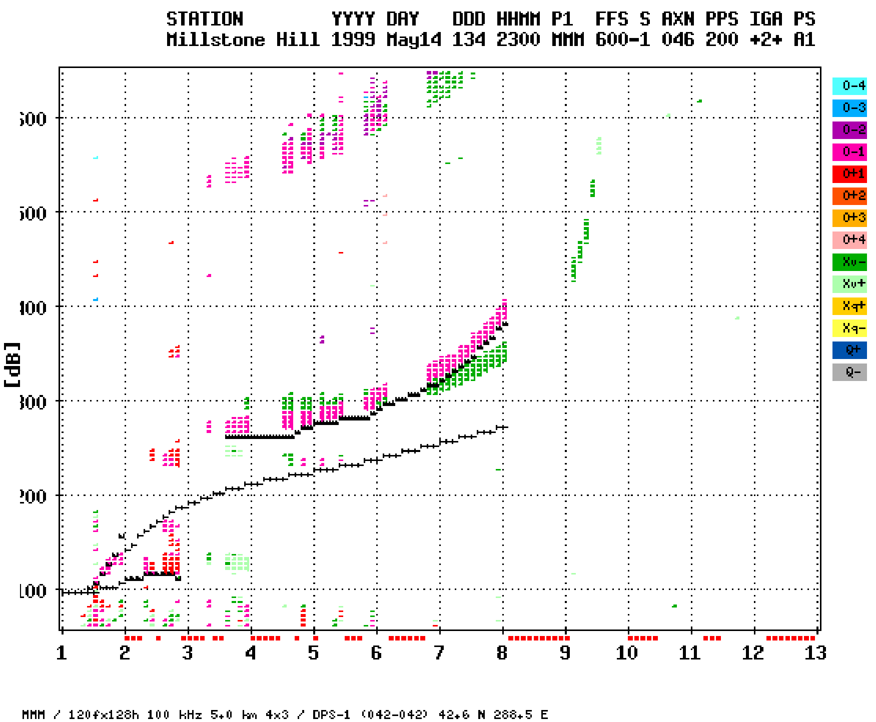
Success: Wallops Island



Minor restrictions mitigate RFI while maintaining data integrity

Failure: Millstone Hill

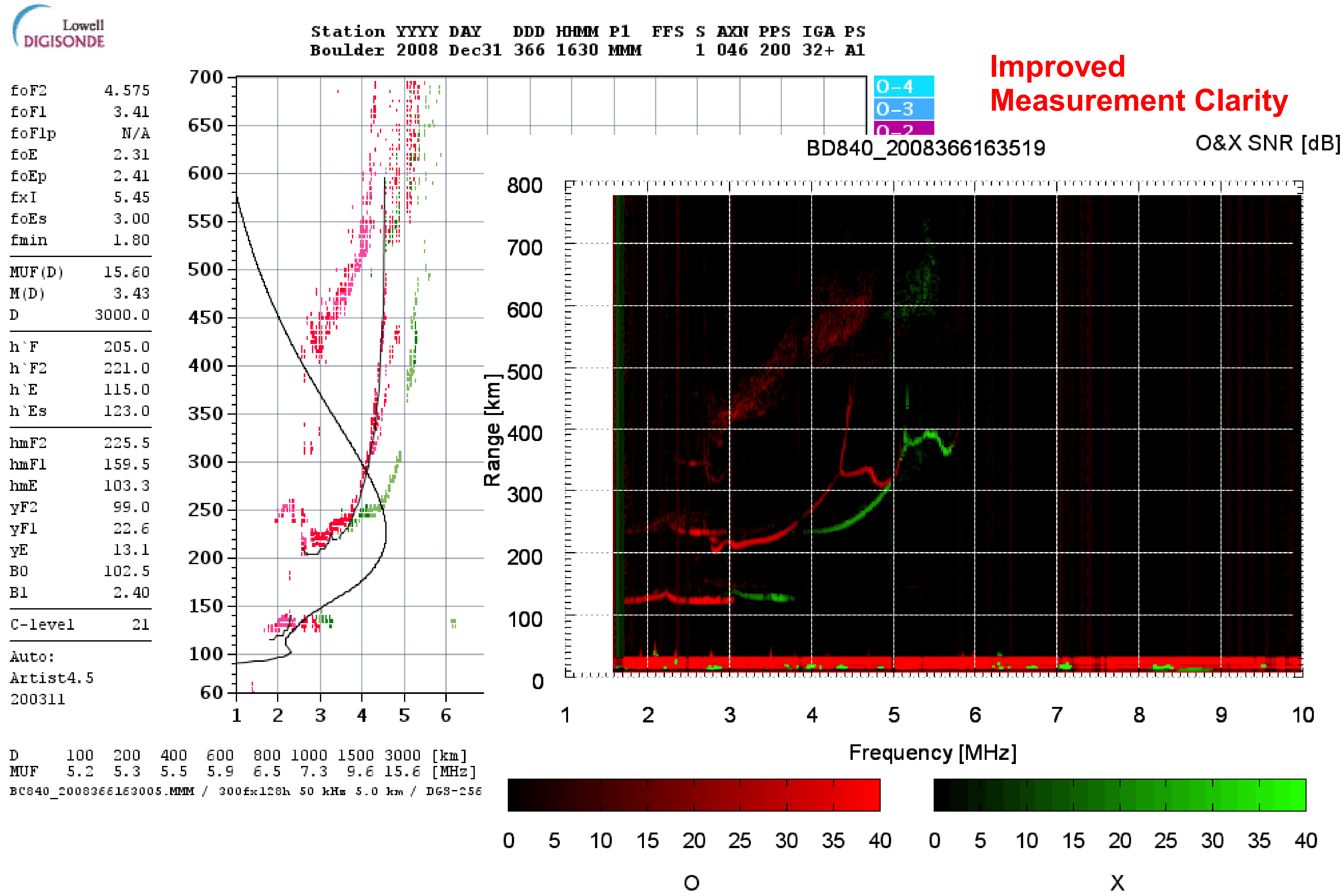




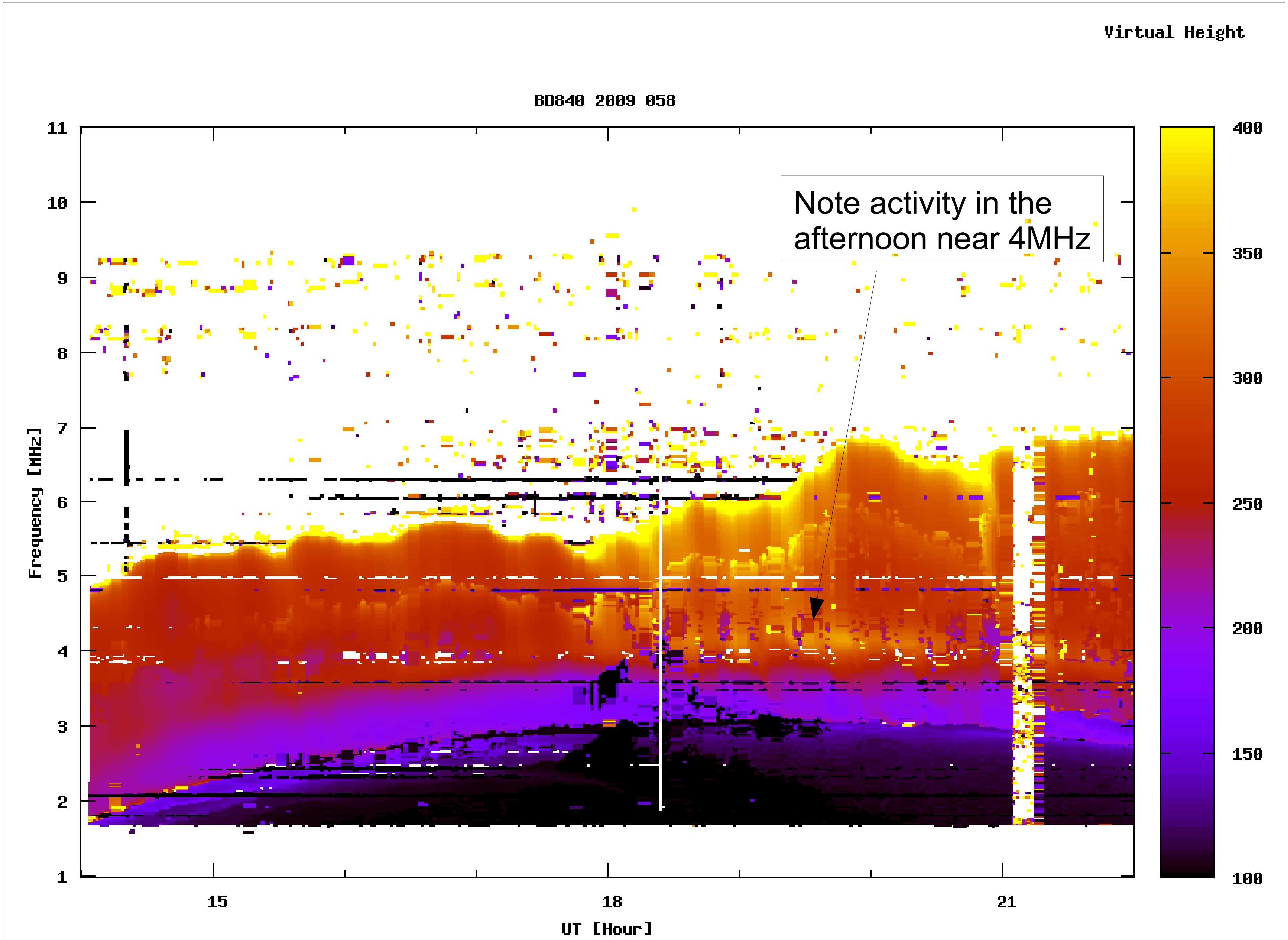
Major restrictions destroy the integrity of the data

Results: Boulder Digisonde vs VIPIR

Improved Measurement Clarity



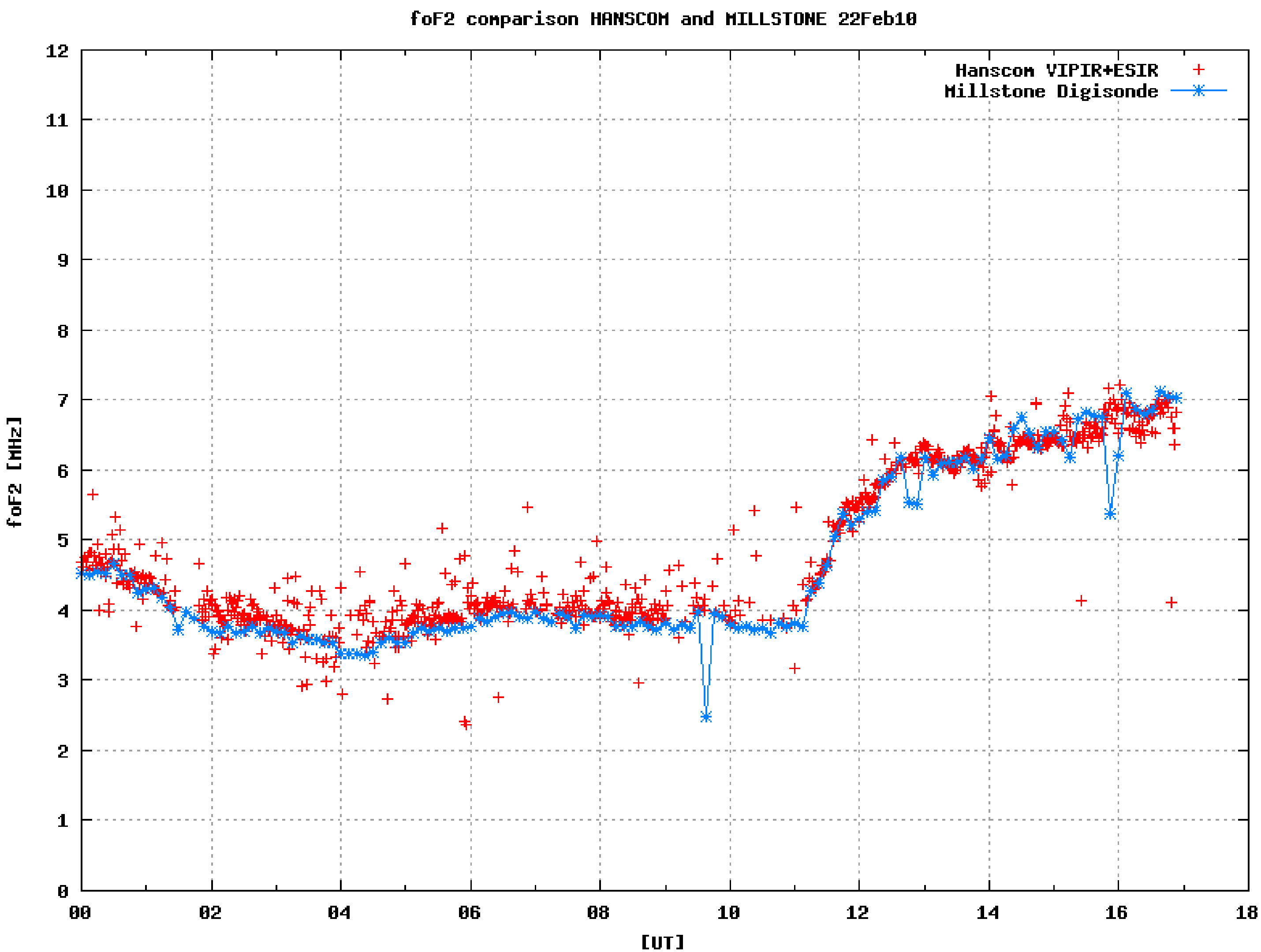
Boulder 1-minute Data



High Time Resolution Data

VIPIR can comfortably make 1 ionogram per min

Digisondes are experimenting similarly

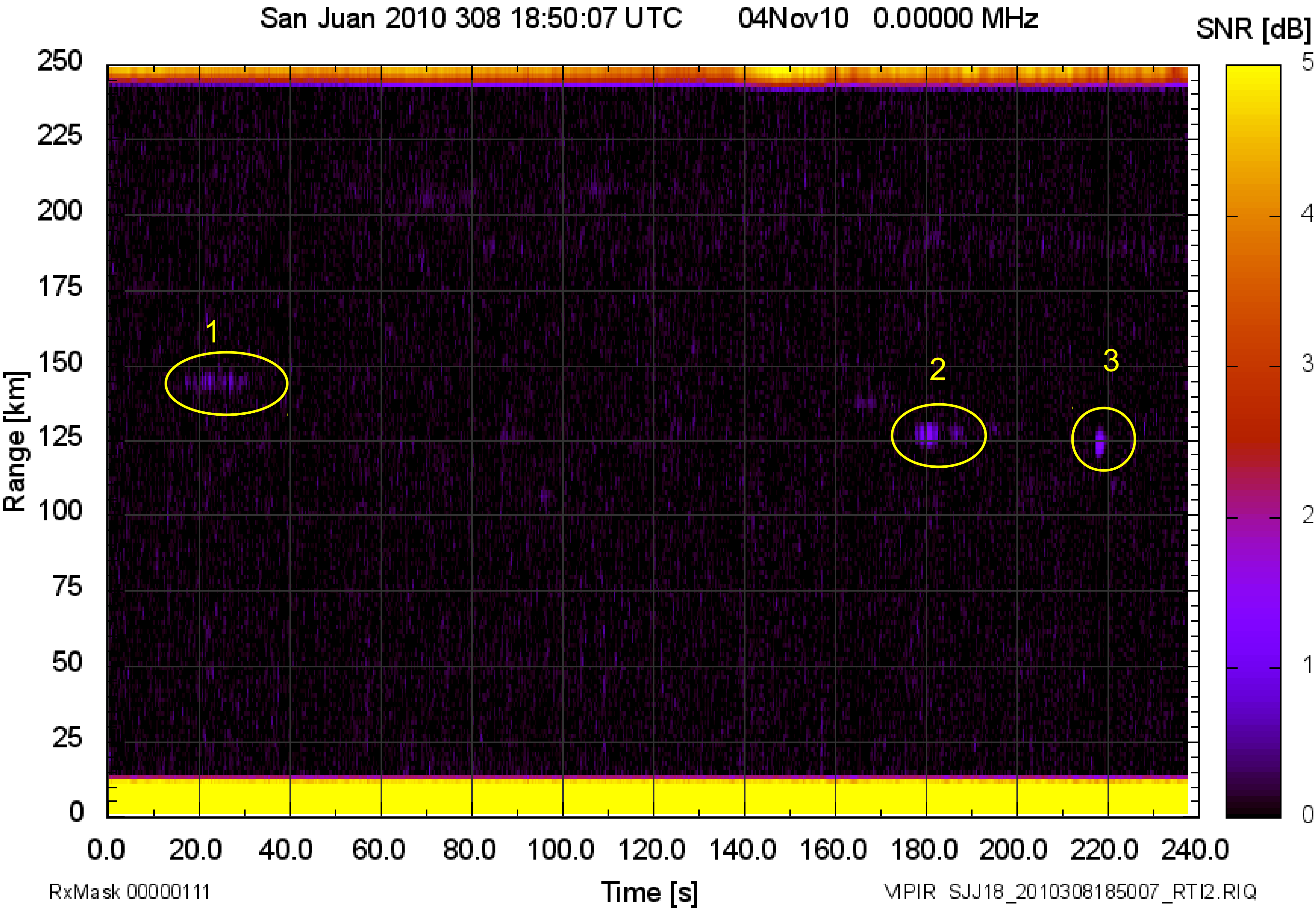


Plot of foF2 for 17 hours from the Millstone Hill Digisonde (Blue) and Hanscom VIPIR (Red)

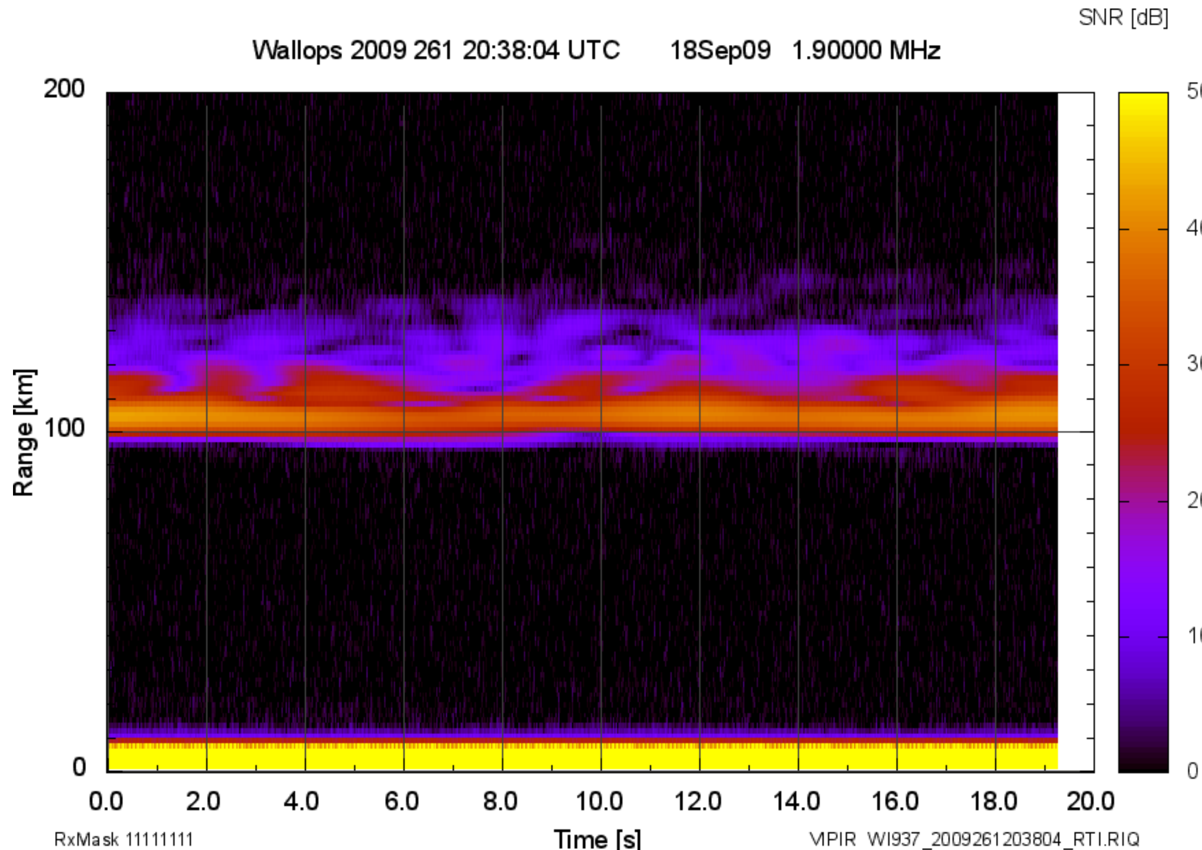
Data courtesy of U.Mass Lowell and Boston College

How to optimally use these data?

Meteor Trails at 5.8 MHz

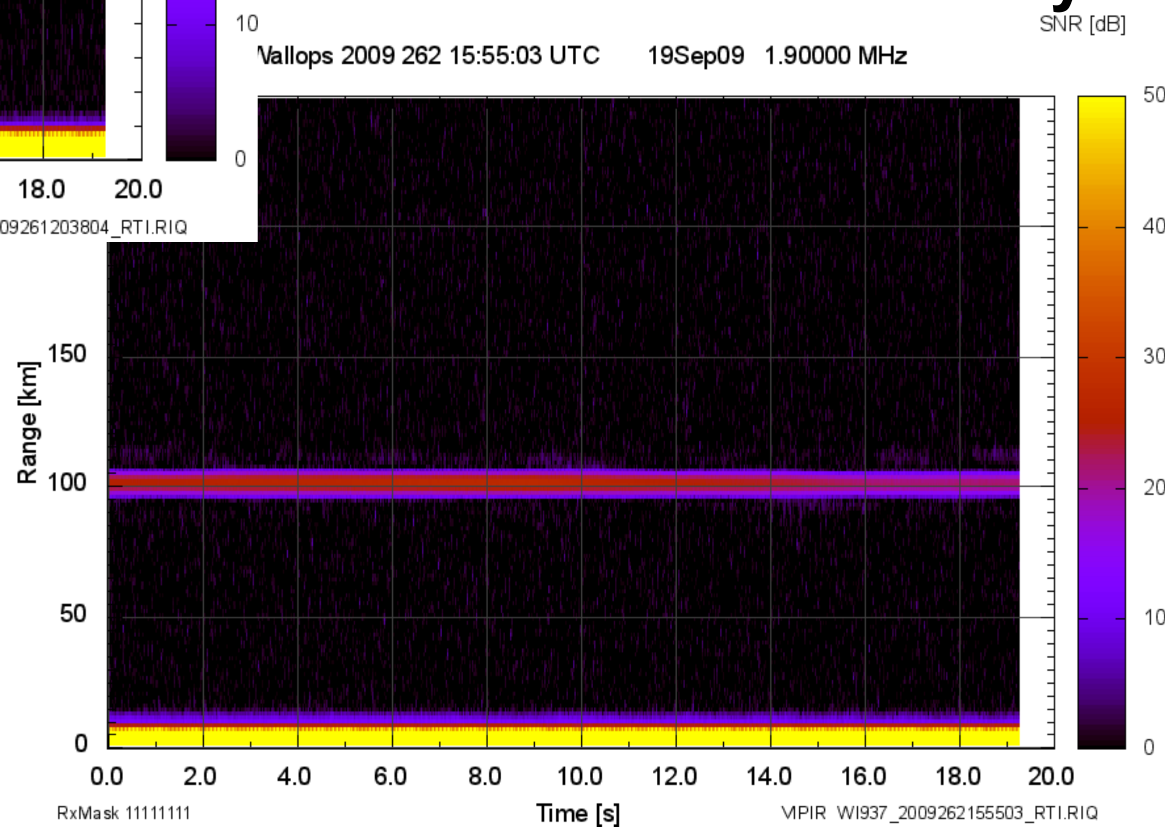


Plasma Turbulence

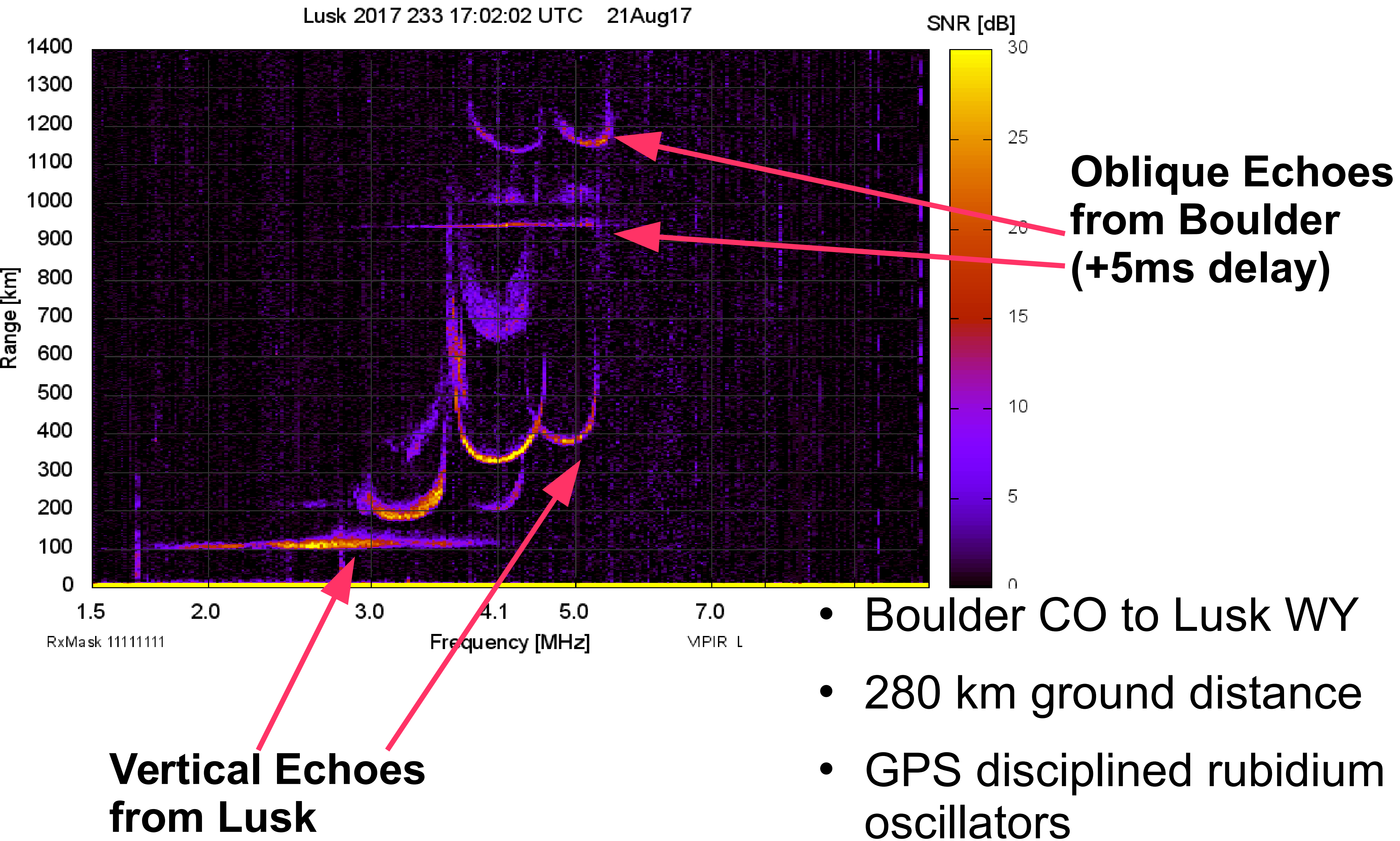


Structured E- layer

Smooth E- layer

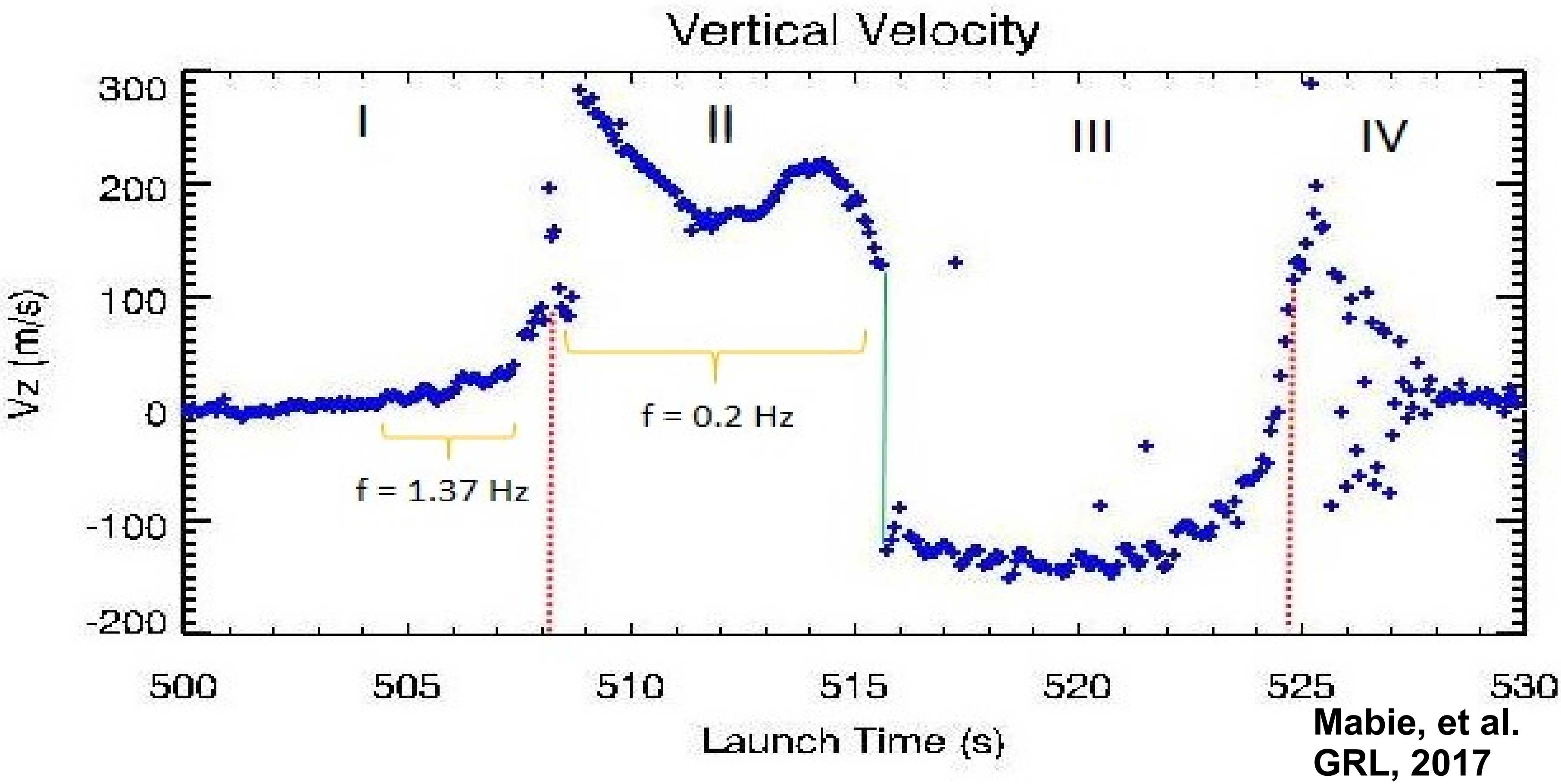


Oblique Propagation – Solar Eclipse 2017



- Boulder CO to Lusk WY
- 280 km ground distance
- GPS disciplined rubidium oscillators
- Simultaneous oblique and vertical sounding

Acoustic waves



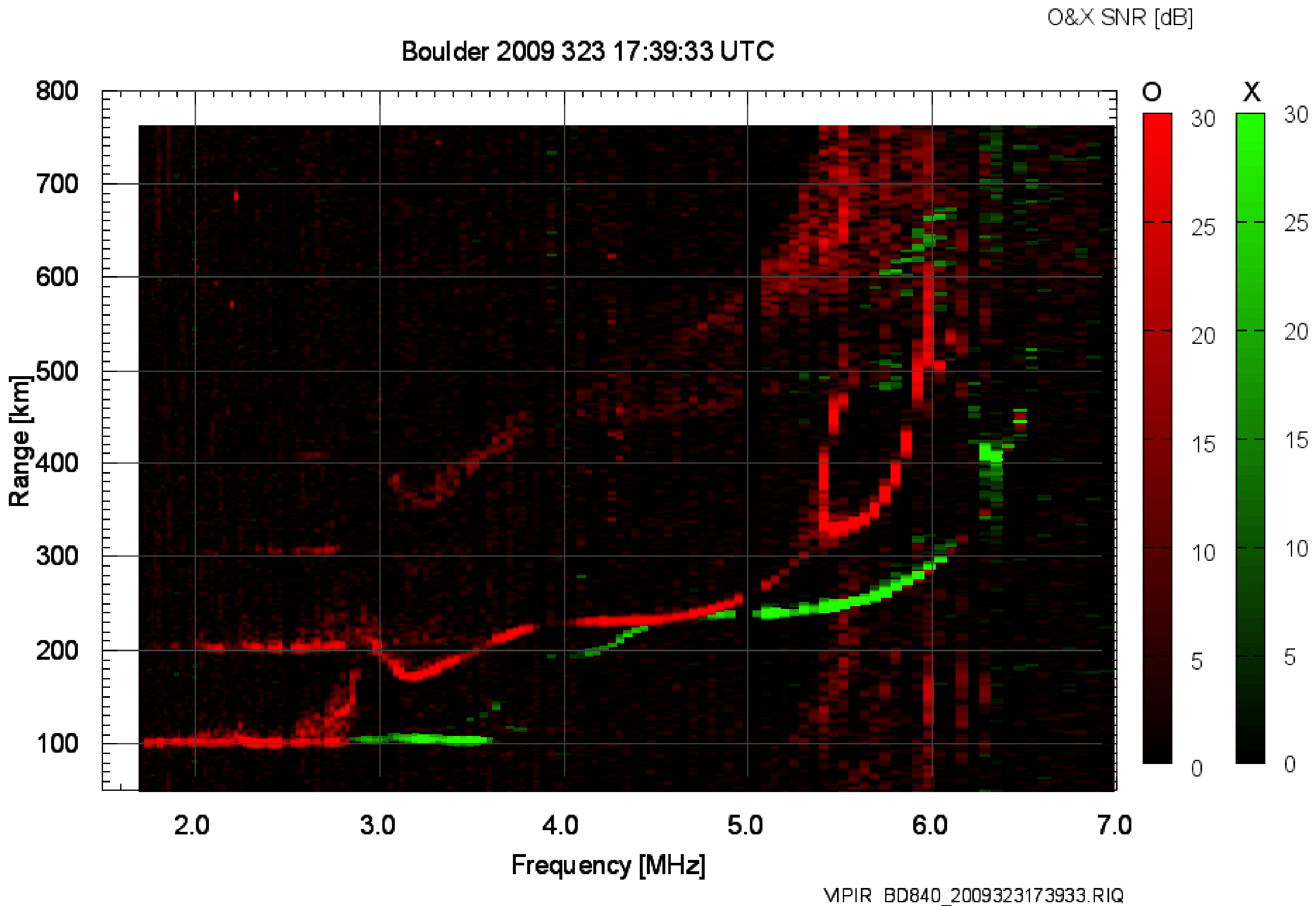
Mabie, et al.
GRL, 2017

- Sound waves from rocket launches perturb the ionosphere
- Possibly similar effects from earthquakes and tsunamis
- Potential to measure sound speed in the thermosphere

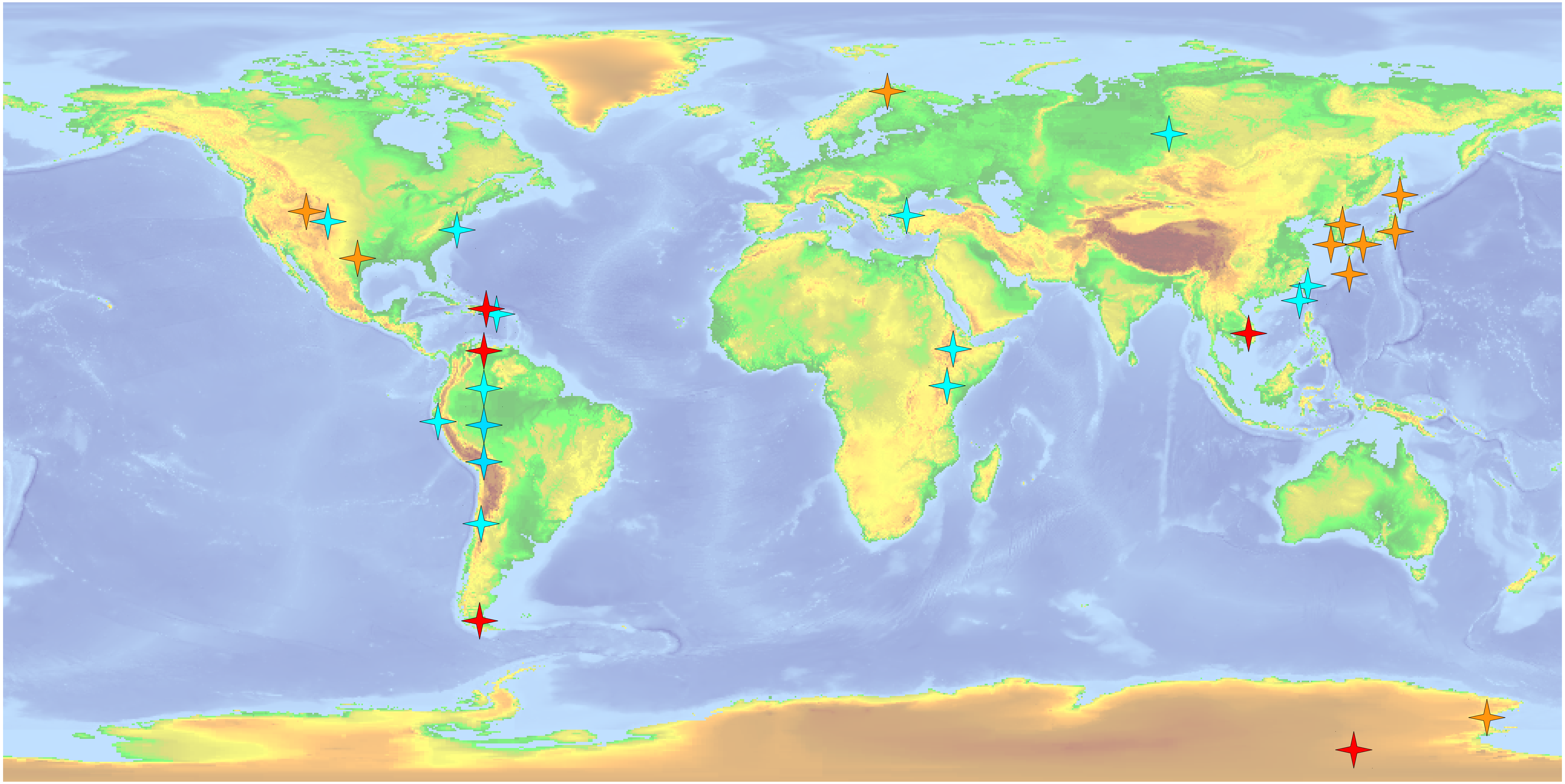
Very Fast Sweeps

Ionogram sweeps < 10 seconds long

Continuous repeat of 100's of sweeps possible



VIPIR Facilities



VIPIR 1 (14) VIPIR 2 (10) Planned (5)

Updated November 2017

Internet Resources

- World Data Center A, Boulder: http://www.ngdc.noaa.gov/stp/IONO/ionohome.html
- Digisondes and ARTIST : http://ulcar.uml.edu/ http://www.digisonde.com/
- Autoscala: http://roma2.rm.ingv.it/en/facilities/software/18/autoscala
- ESIR : http://www.spacenv.com/
- Low-latitude Ionospheric Sensing System: http://jro.igp.gob.pe/lisn/
- Vertical Incidence Pulsed Ionosphere Radar (VIPIR): Terry.Bullett@noaa.gov
- Canadian Advanced Digital Ionosonde (CADI): http://cadiweb.physics.uwo.ca/
- Ionospheric Prediction Services (IPS): http://www.ips.gov.au/
- Ionosonde Network Advisory Group (INAG) http://www.ips.gov.au/IPSHosted/INAG/
- SPIDR: http://spidr.ngdc.noaa.gov/spidr/index.jsp
- Gravity Waves: http://surf.colorado.edu